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PRODUCT ENGINEERING

What's Coming—

Packard engineers have just completed the tremendous task of adapting the Rolls-Royce Merlin XXVIII engine to mass production by American methods. In less than a year they have set up an entirely new engineering division, intensively studied 2,500 drawings and parts and made comprehensive plans for tools and methods, so that by December production will reach 40 a day. The story of this accomplishment will be told in September P.E.

Porcelain enamelling is finding many new applications to circumvent the shortages in stainless steel and aluminum. In a comprehensive article P.E. will give the how and why of designing parts to be porcelain enamelled.

Factors to be considered when electric wiring is required on a machine—type of wire, size of conductor, kinds of conduit and fittings and the like—will be covered in a data-packed article.

The copper alloys series based on Revere Copper and Brass research, supplemented by data sheets on properties, will be continued.

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ENGINEERING SOCIETIES

A.S.A. Approves and Publishes N.M.T.B.A. Lathe Standards

The American Standards Association recently announced publication of a new standard for Accuracy of Engine Lathes, providing a series of 25 tests to be applied in checking the lathes. These include tests for bed level, tailstock way alignment, spindle center runout, cam action, lead screw alignment, and turning work when mounted in chuck or between centers. This standard was developed by the Engine Lathe Group of the National Machine Tool Builders' Association and has already proved its value in practice in machine tool purchases made by the government.

Westinghouse Tells A.I.E.E. of Giant Transformer of Hypersil

A 40,000-kva. forced-air and forced-oil-cooled power transformer with 10 percent lighter windings and 25 percent lighter core, was described before the A.I.E.E. summer convention at Toronto, Canada, by H. V. Putman, Westinghouse Transformer Division, and Philip Sporn, American Gas and Electric Service Corporation.

Utilizing the new magnetic steel known as Hipersil, weight and dimensions of the 138-kv. unit have been reduced so that it can be shipped in oil, completely assembled with bushings in place, on a standard railroad flat car. The cover is welded in place and the unit is sealed. It has no provision for breathing. Using standard magnetic steel, transformers of this size must be shipped in nitrogen in special containers.

MacGregor's "Tension Test" Awarded A.S.T.M. Dudley Medal

For his paper presented at the 1940 annual meeting of the American Society for Testing Materials on the subject "The Tension Test," C. W. MacGregor, associate professor of applied mechanics, M.I.T., was awarded the Charles B. Dudley Medal at the 1941 annual meeting in Chicago.

Mr. MacGregor's paper covered various definitions of strain and reduction of area and related these to true values of strain and reduction of area, deducing expressions which are compared with the accurate relations. A paper presented at the 1941 meeting by Bruce Johnston and Francis Opila on "Compression and Tension Tests of Structural Alloys" gave considerable data on "true ductility indices" which were proposed in Mr. MacGregor's paper last year.

Steel Socket-Welding Fittings Proposed Standards Drafted

A draft of a proposed American Standard for Steel Socket-Welding Fittings, recently completed by a committee of the A.S.A., covers over-all dimensions, tolerances, and marking for wrought and cast carbon and alloy-steel welding fittings. It is now being distributed to industry for criticism and comment. Copies are available on application from the American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Meetings

Society of Automotive Engineers—National Tractor Meeting, Schroeder Hotel, Milwaukee, Wis., Sept. 25–26. John A. C. Warner, secretary, 29 W. 39th St., New York, N. Y.

Chicago Exposition of Power & Mechanical Engineering — International Amphitheatre, Chicago, Ill., Oct. 6–11. Charles F. Roth, manager, Grand Central Palace, New York, N. Y.

American Society of Mechanical Engineers—Fall Meeting, Louisville, Ky., Oct. 12–15. C. E. Davies, secretary, 29 W. 39th St., New York, N. Y.

American Society for Metals—Annual Meeting, Benjamin Franklin Hotel, Philadelphia, Pa., Oct. 20–24. W. H. Eisenman, secretary, 7301 Euclid Ave., Cleveland, Ohio.

American Welding Society—Annual Meeting, Philadelphia, Pa., Oct. 19–24. Miss M. M. Kelly, secretary, 33 W. 39th St., New York, N. Y.

Steel Founders' Society — Fall meeting, Hot Springs, Va., Oct. 13–14. Raymond L. Collier, secretary, 920 Midland Bldg., Cleveland, Ohio.

National Metal Congress To Go All Out for Defense

With its service to the industry emphasized by the national defense program, the National Metal Congress and Exposition, to be held in Philadelphia during the week of October 20, will be more pretentious this year than ever before, advance sales of exhibit space indicate. Each morning during the session, one of the government's leading executives will address the Metal Congress on defense progress and requirements in Army, Navy, aircraft and civilian production. Round-table discussions on armament production will be headed by armament experts.

S.P.I. Urges Voluntary Limitation of Inventories

Officials of OPM have suggested that trade association executives may be helpful in urging limitation of inventories to actual production requirements to defer the need for allocation of materials—a step which will be hastened in the event of a continued trend of extra buying. The Society of the Plastics Industry, feeling it likely that plastics materials will continue to become scarcer, have relayed this request to the plastics industry. Formaldehyde, methanol and synthetic resin molding powders have recently been added to OPM's critical list. The Society is working closely with OPM to determine the productive capacity of the industry, the rate of its production, inventories to production and other pertinent data.

A.S.T.E. to Discuss Older Machine Tools

To what extent older machine tools can be utilized to speed defense production is to be the major topic of discussion at the semi-annual meeting of the American Society of Tool Engineers, to be held in Toronto, Canada, October 16–18. The meeting will seek to determine in a general way whether machine tools are or are not a "bottleneck" in defense work. Technical sessions will be devoted to a general consideration of machine tools for defense work. A feature of the three-day session will be extensive daily plant tours through major defense industrial concerns in the Toronto area.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

Play Hard To Win

TO THE TOTALITARIAN MINDED PERSON it seems inconceivable that the ruling powers of a nation can prosecute its industries and industrialists, pass legislation distasteful to them, commit acts against them that they consider unjust, and then have those same industries and industrialists voluntarily, individually and collectively, give their unstinted support to the defense program of that country. To the German mind, that is impossible. But it is explainable.

The Americans are the world's greatest sport-loving people. In every sport there are rules. And thus the American people have learned to play by the rules of the game. If the team gets a bad break, they make the best of it. They take every possible advantage of the breaks, but play hard and always play to win. That is an American creed, learned in playing in the vacant lots of the tenement house districts, in athletics in the public schools, in competing for and on the college teams, or in playing on the big league teams.

In the atmosphere of our great industrial organizations there are also rules of the game and the same spirit prevails. Our American industries were not created out of government subsidies. The railroads, steel companies, automobile industries, aviation and all our other major industries were reared through sweat and hardships. And in all cases there were rules of the game. If fate was unkind, if the going was hard, if legislation hampered, more determination and more sweat was put into the job. When industry was called upon in the defense program, industry had only one answer—"Let's go." It undoubtedly never occurred to any worthy industrialist to hold out for more lenient legislation relating to business. Such an attitude would have been inconceivable; the rules of the game in a democracy do not permit it. No sane man would have tried it; public opinion would have denounced him thoroughly.

Today the powers in Germany are undoubtedly contemplating our defense program with scorn and derision. And well they may. Industry is asked to put on full steam and risk tremendous losses through possible over-expansion and at the same time is subjected to prosecution and caustic criticism by government officials. For example, in the forefront of this industrial expansion program is the Aluminum Company of America. Entirely at its own expense and risk this company expanded its production program several fold, anticipating the needs before the defense program got into full swing. And behold the spectacle. At the very time that the Aluminum Company of America is putting forth every effort, even to the extent of loaning its best technicians to competing companies, the very government it is trying to help is putting forth an increasing effort to convict it of misdeeds.

Perhaps not satisfied with the zeal with which he is prosecuting the Aluminum Company of America, Thurman Arnold, Assistant Attorney-General, presents an article in an internationally read magazine in which he makes stinging accusations. The implications in the article make it appear that Mr. Arnold is saving the world for democracy by compelling industry to "toe the mark." But to any informed engineer his errors and inaccuracies in engineering data presented in his article are glaring. They lead one to think that many of his other assertions are perhaps likewise misleading.

What a spectacle. No wonder Hitlerdom does not believe the U.S.A. can "do the job." No wonder that even some people of the U.S.A. are doubting the efficacy of the defense program. But the defense program is rolling, rolling at an ever-increasing speed that has now carried it beyond the objectives set originally. Why? How? Because Americans are the world's greatest sport-loving people. Petty politics and self-aggrandizement are brushed aside and ignored when there is a real job to be done.

The Nazi mind is incapable of comprehending that in the U.S.A. we play by the rules of the game whatever the rules may be and whether or not we think the umpire is fair. When the goal line is established, there can be only one objective—cross the goal line as soon as possible.

The goal has been established. We are blessed with an Army and Navy better organized than ever and with our Industrial Organization, the world's greatest, geared in with our War and Navy departments almost perfectly. These two alone are now shouldering the major burden. It is time for all to get in the game and, regardless of the breaks, play hard and play to win. Discount 100 percent the tirades of the crepe hangers and the pettiness of politicians. Only by winning for the cause of democracy can we continue to be what we are—the land of the free.

U.S. ARMAMENTS SUPERIOR

GEORGE F. NORDENHOLT

Chrysler from O.E.M.

(Left) K. T. Keller of Chrysler; (center) Major-General Charles M. Wesson, Chief of Ordnance. Brig.-General G. M. Barnes (right) is Assistant Chief and is active head of the Committees on Development and Manufacture of Armament

QUANTITY and quality of armaments and the effectiveness with which they are used determine victory or defeat. Seven years of sacrificing "butter for guns" placed Germany far ahead of all other nations in these three essentials for winning battles and conquering peoples. And Hitler has made the most of it. Today the question upppermost in the minds of liberty loving people is whether or not the democracies that are still free can overtake and surpass the best efforts of Germany. The only hope for this lies in the possibility of the United States to do so with the aid of the British Empire. This may sound like putting it in reverse. But a thoughtful consideration of the situation forces one to the conclusion that the United States must play the major role in furnishing the equipments for war if Hitler's aim to make the Nazis the "masters of the world," as he expressed it in the second from last paragraph of his book "Mein Kampf," is to be thwarted.

When our defense program was started in June 1940, it was glaringly obvious that we had no substantial quantity of modern fighting equipment. Worse still, we did not have finished designs ready for mass production. The fighting planes we sent to England had to be partially rebuilt because they lacked protective armor and needed more guns. We had no up-to-date designs of tanks comparable with the Germans. Even today, the design of the heavy tank is not complete.

A year ago many people freely predicted that we would go through the experiences of World War–I all over again. They recalled the chaotic conditions of that period, how the lack of standardized specifications, the innumerable errors in ordnance drawings and the maze of red tape made a shambles of all attempts to get the ordnance equipment manufacturers into mass production. Those were the days when it was necessary to write a letter to Washington to get authorization to correct an obvious technical error. There was such an abundance of such errors and other technical questions that the letters to Washington swamped the desks of the officers. Many of the letters went unanswered for months while the machinery of production stood all but still. When the war ended, which was almost three years after our preparations for war had begun, only an insignificant amount of some of the most important ordnance equipments for the U. S. Army was in France.

Hearing these stories, the man on the street wondered; many are still wondering. What had been done since 1920 so that the sad experiences of World War–I would not be repeated? In addition to the stories that went the rounds concerning that period, the general im-

U. S. Army

Railway-mounted gun in action. Ordnance design covers almost every conceivable field, hence the importance of the Ordnance-Industry collaboration as now established

pression has been that our Army and Navy has been asleep for the past 20 years. Well may the U. S. citizen think so because he did the best he could to make it so.

From the close of the World War to 1937, military activity in the U.S.A. was extremely unpopular, so unpopular that Congressmen would probably have been afraid to have passed reasonable Army and Navy appropriations. So clearly was this recognized that the appropriation asked for by the War Department's Budget Bureau permitted allocating only a skimpy $12,000,000 average per year for the total to be spent on the six arsenals, Aberdeen Proving Ground, plus expenditure for research and development work and the purchase of small quantities of material.

The paltry $12,000,000 per year was spent as carefully and effectively as possible. And the Army officers then turned to industry for help. But because of the oft repeated cries of "war mongering" industrialists had to be extremely careful in giving free aid to the Army. In one instance, early in the twenties arrangements were made whereby Bethlehem Steel was to make metallurgical researches and sample shells, free of all costs or obligations. The shells were to be furnished to the Army for making ballistic and fragmentation tests at the proving grounds. All the facts, data and research records on this project were to be given freely by Bethlehem Steel Company to the Ordnance Department. The purpose of the project was to develop a superior shell steel. But then came the Nye investigation and for fear of being misunderstood and labelled as a "war monger" Bethlehem Steel buried the project.

However, gradually there developed direct voluntary cooperation between the military and naval leaders and industries. The first program of this nature was the Federal Specifications Bureau. It is safe to say that without the active voluntary participation of industries, particularly through the medium of the national engineering societies, this whole project would have failed. Indeed, Congress apparently took little or no interest in it, perhaps because the project was instigated by the Army and Navy and hence had a militaristic flavor. In any event, in many instances no funds were available to pay the expenses of Army and Navy officers and civilian engineers of the Army and Navy to attend committee meetings outside of Washington.

According to a member of one of the A.S.T.M. committees, a metallurgical

Medium tank being made by six manufacturers. In fourteen months the design was perfected, plants built and tooled and the tanks delivered in quantity

Chrysler from O.E.M.

Under the Army-Industry method of cooperation, engineers of industry perfect design details. Here Chrysler engineers study the castings for the 28-ton tank

engineer employed in industry. "For years we held our B-5 Committee meetings in Washington because the Army and Navy boys couldn't get travelling expense allowances." Directly or indirectly, industry paid most of the costs to establish Federal Specifications. (See "Engineering for Defense," P.E. Nov. 1940, p. 504, for a detailed account of the establishment of Federal Specifications.)

In spite of all difficulties and handicaps, and the antipathy of the public against all things militaristic, gradually closer ties developed between men of industry and officers of the military and naval services. At the same time that the Federal Specifications project was in progress, Ordnance Department officers took stock of their particular situation and studied the possibilities of obtaining the help of industry. Theirs is a big job. The Ordnance Department is responsible for the designs of more than 1,200 major items of equipment involving about 250,000 important components. To keep these designs up-to-date, and to check and perfect the detail drawings and specifications involved was a much bigger job than the Ordnance Department could hope to handle with the small funds at its disposal. Industry was asked to help, and industry responded.

With industry taking over the bulk of the load in studying ordnance drawings and specifications, the Ordnance officers were able to concentrate their efforts on studying foreign weapons and improving the overall designs of their equipment. Observers stationed in foreign countries sent in detailed reports of developments in armaments. Models of equipments of foreign design were subjected to tests at our proving grounds. Basic designs of improved equipments were developed and pilot models built in our arsenals and tested at the proving grounds.

Referring to the help rendered by American industry during the period since the World War, Brigadier General G. M. Barnes stated in his article appearing in the magazine *Army Ordnance*, "Industrialists had cooperated fully with the Ordnance Department and had spent considerable sums in studying ordnance drawings and specifications—no funds then (1920–1937) having been appropriated by the Congress for this purpose."

This whole program was tied in under the name of Industrial Mobilization. Misunderstanding of this plan sponsored by the Ordnance Department led some people to believe that the expectation was that the plan would enable industry to pour forth ammunition the day after a rearmament program was started. But such an impossi-

bility was not the objective. However, the Mobilization Plan and all the other cooperative activities of the Army and Industry did have one result which was probably unforeseen. The army officers and industrial engineers became well acquainted with each other.

When the program to rearm was launched in June 1940, the Ordnance Department was ready to swing into full action immediately. And it did. The "semi-official" relationships between the Ordnance Department and Industry were developed into an officially functioning organization. Ordnance officers mapped out a proposed program in which industry was to assist the Ordnance Department directly in the work of perfecting equipment and other Ordnance designs and getting defense production rolling quickly. When the army officers explained the plan, Industry accepted it with enthusiasm.

Under the Ordnance-Industry cooperation plan, manufacturers were asked to designate one or more engineers to serve on engineering advisory committees to meet with qualified Ordnance officers and Ordnance engineers. At such committee meetings there would be free and open discussions of questions relating to the designs of ordnance equipment, the materials used, possible improvements, manufacturing problems, drawings and all other factors.

As finally organized, there are about 40 such committees and sub-committees, each covering a specific kind or type of equipment. For example, the best engineers of the manufacturers of equipment relating to or similar to war tanks, serve on the Tank Committee with Army officers who have made tanks their special study. Engineers of companies engaged in or intending to be engaged in the manufacture of cartridge cases are assigned by their company to serve on the Cartridge-Case Committee, and so on.

Besides these Ordnance Engineering Advisory Committees there are also Research Advisory Committees, both groups of committees functioning under the general title of "Ordnance Engineering and Research Committees on Development and Manufacture of Armament." Brig.-Gen. G. M. Barnes heads the organization. It should be noted that this whole organization is independent of, although coordinated with, the Federal Specifications Committee.

Skeptics may doubt the effectiveness of designing ordnance by such a "committee" method. But it must be emphasized that the Ordnance officers establish the performance requirements and general specifications of the equipments to be made. The committees function solely to solve the factual problems posed by the ordnance engineers. The industrial representatives are men who can quickly tell what can be done most effectively, how the same results might be obtained more readily, how the mechanical aspects of the designs might be simplified, and how the designs might be modified to permit faster production.

The operation of these Ordnance Research and Advisory Committees can be most effective only when the cooperation is enthusiastic. The groundwork for that kind of cooperation was laid during the twenties and thirties when the Army officers started hob-nobbing with industrialists in order to make the best of a sorry situation—the dearth of Army appropriations. One might say that the scanty Army appropriations were a blessing in disguise.

"The response of American industry to our invitation to form committees and to send their representatives to the meeting to be held in Washington, at various arsenals or wherever the committee might decide, has been spontaneous and complete," stated Brig.-Gen. G. M. Barnes in his article in *Army Ordnance*. But a clearer idea of the nature of the cooperation is gained through conversations with officers and civilians serving on the committees.

As an example of how such committees form and function, there is the Sub-Committee for Cast Armor.

One of the major problems in the design of a tank is the armor plate. For several reasons it was desirable to use cast armor instead of rolled and fabricated armor which requires riveting or welding in its assembly. But up until less than a year ago there was no such thing as cast armor. It had always been considered that cast armor would necessarily be inferior simply because it was cast. But the engineers of Rock Island Arsenal let it be known that they would find it very valuable to have cast armor. What its chemical composition should be, how it should be heat-treated, how it should be made, they had no idea. The only thing they were able to specify was that the cast armor had to be able to stop a shell and that it was not to shatter or break into fragments if a shell did penetrate it. The Ordnance Department asked the cooperation of American steel foundries.

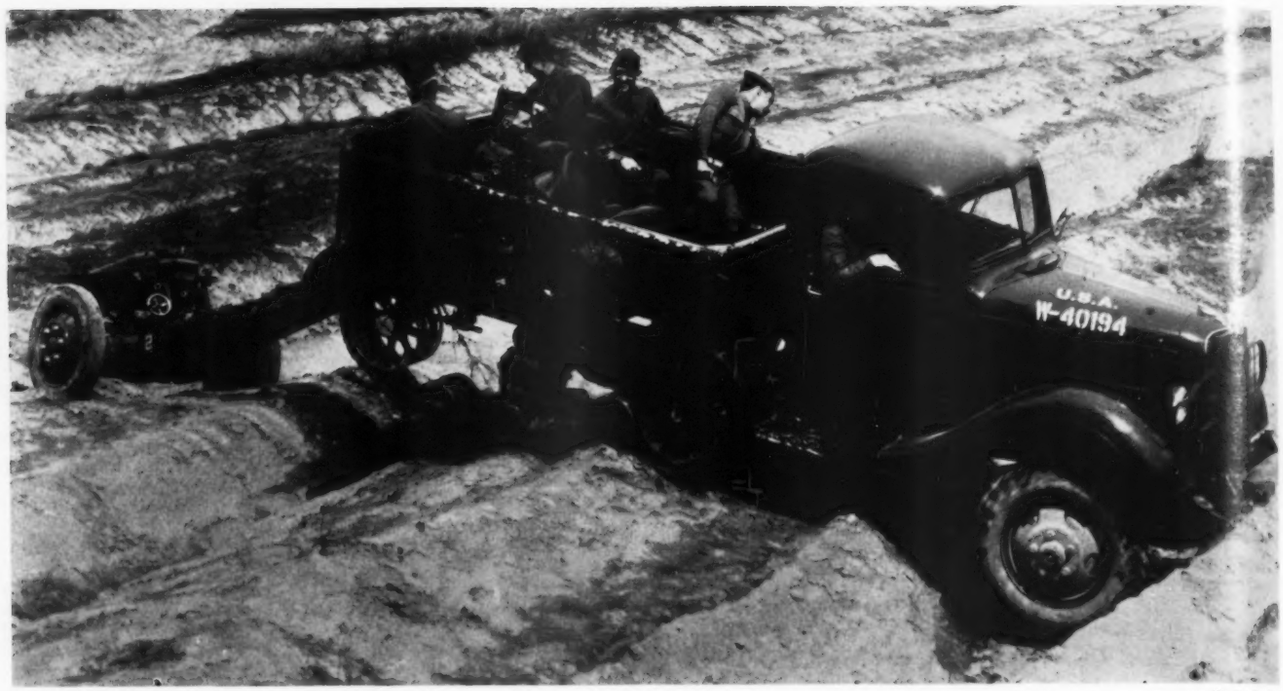
Immediately four steel foundries volunteered to cooperate freely in the development of cast armor and four more came along soon after. These eight steel foundries assigned the best metallurgical and foundry-practice brains of their organization to work with the "service representatives," that is, officers and engineers of the Ordnance Department. Thus the Sub-Committee for Cast Armor was formed. Not only did the foundries contribute free of charge the services and travelling expenses of these experts, but they also made numberless samples of cast armor of different chemical compositions, heat-treatments and thicknesses. The samples were tested at Aberdeen Proving Grounds and the results reported to the foundry that made the samples.

The Sub-Committee for Cast Armor meets at frequent intervals both just among themselves to swap ideas and also in official meetings with the Ordnance officers. It is not a case of each of eight foundries cooperating with the Army; it is the experts of eight foundries pooling their best knowledge and experience and giving it to the Army. And it should be emphasized that the foundry representatives are not "brass hats" or salesmen, but the best metallurgical brains in the respective organizations. On this committee are Dave Zeuge of Sivyer Steel Castings, C. F. Landgraf of Lebanon Steel, R. A. Gazelius of General Steel Castings; W. C. Hamilton and C. G. Michelson of American Steel Foundries, W. B. Libert and R. C. Heaslett of Continental Roll & Steel, C. N. Arnold of Union Steel Castings Company, W. J. Phillips of Symington-Gould Corporation, and C. F. Wehr and A. T. Baumer of Wehr Steel Company. They are all authorities in metallurgy and foundry practice. And each has his staff, laboratory and foundry to bring to bear on the solution of any foundry problem.

Likewise the "service representatives" are all men who have specialized in the problems relating to armor plate. Office of the Chief of Ordnance is represented by Majors J. E. McInerney, J. H. Freye and W. J. Crowe. Aberdeen Proving Ground where they put the tanks through their paces is represented by Captain J. L. Atkins and H. J. Rouse. Other service representatives include H. A. Curtis of Rock Island Arsenal, Col. S. B. Ritchie of Watertown Arsenal and officers from the Navy Department, Bureau of Ordnance. Thus, on this sub-committee are men from Aberdeen who know how tanks should perform, men from the arsenals who know the manufacturing problems involved and the men from the foundries.

When it was suggested to an arsenal engineer that the foundries ought to be willing to cooperate because they must find their army contacts profitable, the answer was an explosive, "Hell, no! All those foundries now have more work than they can handle. When they do get an order from us it means that they have to throw out some commercial work on which there is more profit. There is not much profit in war work these days."

When an Army officer serving on this committee was asked about the cooperation the army was getting from the foun-



U. S. Army

In anything automotive, American industry is supreme. Army officers not only know it, but are taking full advantage of it

dries, his answer was, "Splendid." A remark by one of the foundry men was, "The Army men are more than open-minded. They not only want our suggestions and advice, they invite it. And we always try to give them something better than what they ask for."

After talking separately with various members of this committee one is strongly impressed by the evident spirit of mutual respect, enthusiasm and co-operation. There are no secrets between them. If one foundry hits upon something that looks particularly good, the representative of that foundry tells the others all about it. Although officially and as a matter of courtesy, the Army reports the results of tests only to the foundry that made the sample tested, actually the results of any and all tests become common property. The foundry engineers not only tell about their samples that gave outstanding results but they also go into complete detail of how they made that particular sample, its chemical composition, how it was cast, its heat-treatment and everything else known about it.

Again taking as an example the design of a tank, the complete procedure would be about as follows: Officers of the Office of the Chief of Ordnance, the branch of the service that will use the equipment and officers from the proving grounds get together and determine the desired performance characteristics of the tank to be designed. Based upon tests, reports from foreign observers, and the experiences of the using arms, that is, the tank corps, specifications such as fire-power, maneuverability, armor, speed, trench crossing ability, fordability and many others are established. From such a start, ideas get crystallized into a basic design.

All conceivable means are resorted to in order to make certain that the proposed design will embody the features desired. A wooden mock-up or model is made to full-size with dummy guns, instruments and other major elements in position. As a further step, an old model of the same type tank is rebuilt to incorporate some of the features desired in the new design and then subjected to proving grounds tests. The experiences in the development of former models and the lessons learned from European battle fields are drawn upon. Finally, everything is ready to begin on the actual production design.

During the period of preliminary design, Ordnance officers and engineers of Rock Island Arsenal are in close touch with engineers of industry, the industrial representatives who serve on the Tank Committee and the Research Advisory Committees dealing with designs of main elements of a tank. Among these committees is the Society of Automotive Engineers Ordnance Advisory Committee with its sub-committees on Rubber Products, Power Plant, Track and Suspensions, and Transmissions. The personnel of these committees includes the best brains of the American automotive industry. Sponsored by the Society of Automotive Engineers, working hand in hand with the Ordnance officers, whenever a special problem arises that requires further technical talents the S.A.E. in consultation with Ordnance officers may suggest the men best equipped to cope with that peculiar problem.

During preliminary study by the Ordnance Department, developments in the design of major components are underway. For example, engineers of the Ordnance Department worked with engineers of Wisconsin Axle Company, Timken-Detroit Axle Company, Mack Truck and others in the development of the design of the transmissions for the medium tank. A "pilot" transmission was built and tested by Mack. Another one was built by Spicer Manufacturing Company for Chrysler. Similarly, General Motors, Wright Aeronautical, Continental Motors and other engine builders pooled their knowledge and experience for the perfection of the design of the engine required. The power unit selected is a Wright Whirlwind, modified to suit and being built by Continental Motors and others.

Similarly, the engineering and research specialists of industry were called upon to develop the designs of the communication systems required, the tracks, the mountings and the many other elements that go to make up a tank.

When the general design was ready there was still work to be done to coordinate the design elements and iron out details. The committees kept on working. The rubber block tracks had to be shielded so that their static would not cause radio interference, the engine

had to be installed so that it would receive proper cooling, instruments and communications devices had to be mounted so that noise and vibrations would not interfere with their operations. These and a host of other problems had to be solved. But with the tremendous man power and the abundance of specialized talents brought to bear upon the problems by the collective efforts of the experts of industry, they were all solved relatively quickly and highly effectively. The design of the tank rapidly reached the point where tools, jigs and machine capacity required for manufacturing could be visualized.

This sounds like a long time-consuming process, but considering the size of the project, the speed in the design of the medium tank was amazing. In June 1940 the Ordnance officers began from scratch, but of course with a big fund of data, information and experience to go on. That is, they were up-to-date on what was needed. By September 1940 the layout of the medium tank had crystallized. By October 1940 pilot models of major components had been built and tested and the tank manufacturers had meetings with the Ordnance officers to iron out the last details of the design. Orders were placed. In May 1941 the first production models were completed and in June finished medium tanks started rolling off the production lines, almost exactly a year from the day when the project began from scratch. In that time not only were the designs perfected but a manufacturing plant was built, tools, jigs and gages made, manufacturing organizations assembled, and materials procured. Now finished medium tanks are coming off the production lines of the six manufacturers daily. Such is the power of the new coalition of the U. S. Army-Navy and American Industry.

It must not be assumed that this industrial cooperative effort is confined to the Ordnance Department. In all the myriad phases of defense preparations the same general relationships exist. All barriers between Army men, Navy men and civilian engineers and Industry have vanished. Civilian engineers are getting first hand information about ordnance requirements and are rapidly learning the special techniques and requirements involved. Ordnance officers are likewise profiting by a better insight into the problems of the American mass production system. Each is profiting. And thus the full power of American engineering and research talent is being brought to bear in a most effective manner upon the design of armaments superior and their manufacture in the shortest time possible.

Thus did the career men of the Army and Navy bring about the most powerful coalition the world has ever seen—a united industry working in closest cooperation with the Army and Navy officers. The world's greatest production organization, American industry, has not only dedicated itself to the building of the greatest quantity of war equipments ever made, but it is also bringing to bear the united power of its engineering and research talent on the solution of the problems relating to the design of armaments. Working under the guidance of Ordnance officers who know what is needed, with every one cooperating with enthusiasm and with all striving for the one objective of superiority of equipment, armaments of ever greater effectiveness are being developed.

Results are beginning to show already. Our present planes are said by the British to be in many respects far superior to the best of Europe's. Our latest design of medium tank has shown to be in proving grounds tests vastly superior to Germany's best. Our scout cars and armored cars are far ahead of all others in all respects. Our Navy building program is from six months to a year ahead of schedule. By the end of this year we will have produced more scout cars, light armored automobiles and motor trucks than an army of 2,000,000 men could use.

Hitler has freely admitted that in his opinion no power could cope with the U.S.A. backed up by its tremendous industrial organization. But he expressed the opinion that American industry would be too slow getting started to produce the required armaments soon enough to affect the outcome of his blitz. Apparently he had in mind the conditions of World War–I. He did not figure on united military-industrial effort wherein the forces of each are coordinated and both brought to bear with enthusiastic cooperation on the vast project of arming on a colossal scale, so huge that it is dwarfing the mightiest efforts of the Nazis "butter-for-guns" program. It is entirely beyond the comprehension of German minds that the prime fundamental of democracy, spirited cooperation, can be applied in such a powerful manner for the defense of democracy. But it is, and that is why U.S. armaments will pour out of factories in abundance, and that is also why these armaments will be superior, and in their application—supreme.

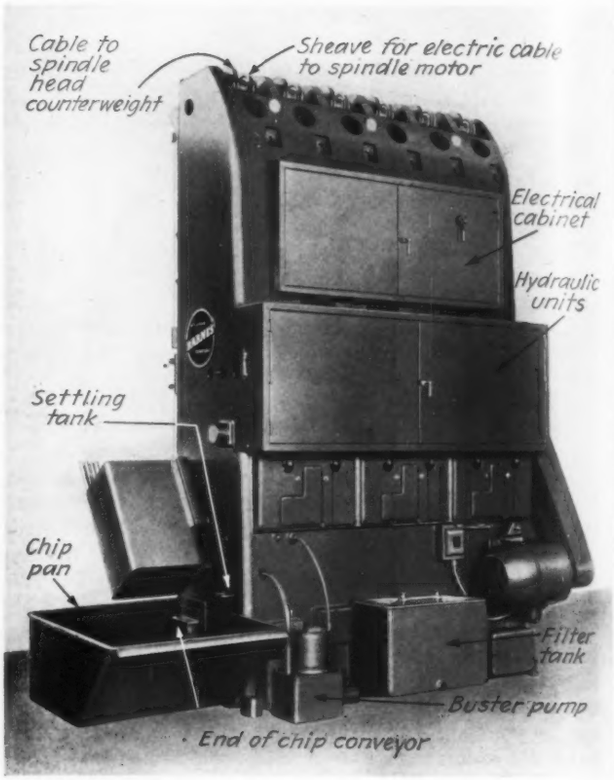
U. S. Army

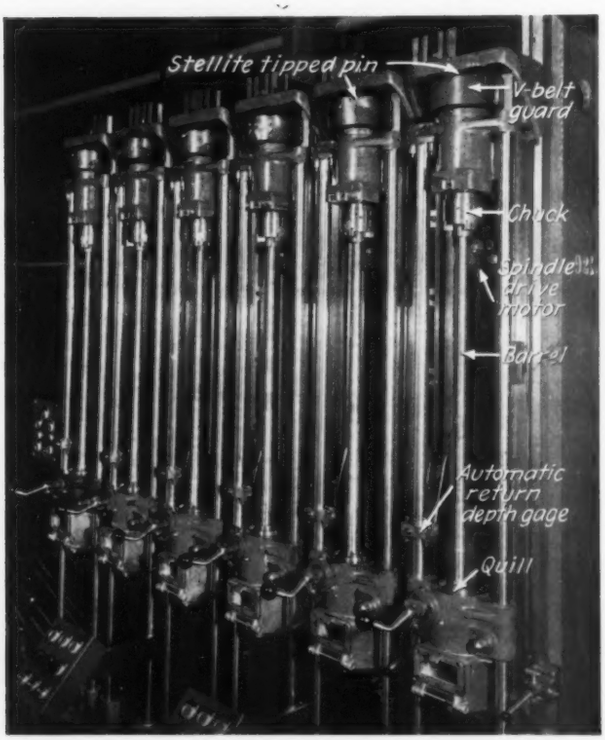
New light-weight tanks in practice attack formation at Fort Knox, Ky. Some of the tanks did not have their guns when this picture was taken, but production of equipment now has been speeded up enough to fully equip a new division every three months

Modern Designs

Multi-Spindle Rifle Drill

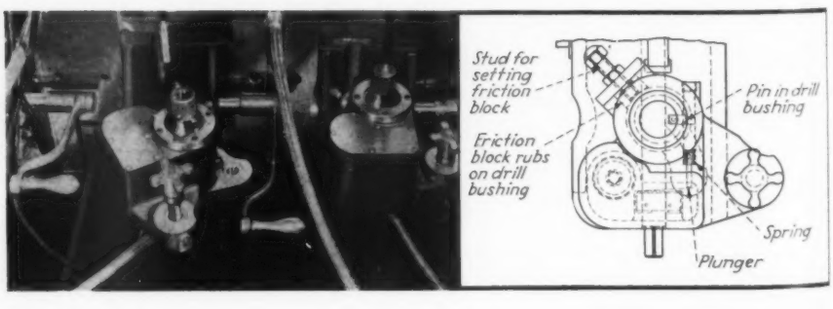
Six-spindle vertical machine, designed by W. F. & John Barnes engineers for drilling rifle barrels, accomplishes a 50 to 85 percent saving in floor area by operating in a vertical rather than a horizontal plane and by compact arrangement of the machine itself. Each spindle head has individual hydraulic actuation, motor for chuck rotation and coolant pump. Chip disposal, lubricant and filtration and quick drill changes are also provided.

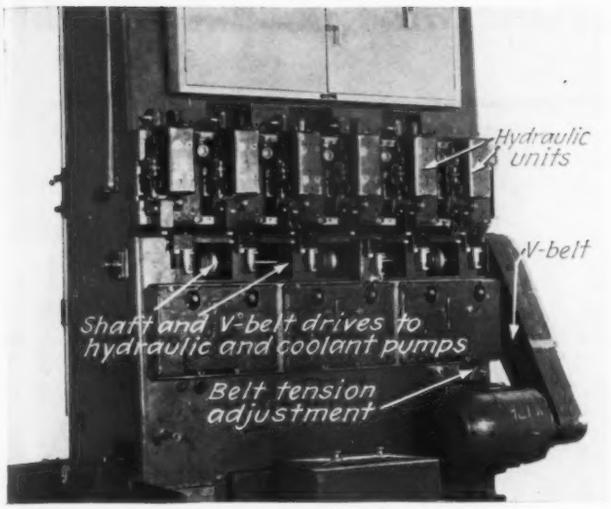




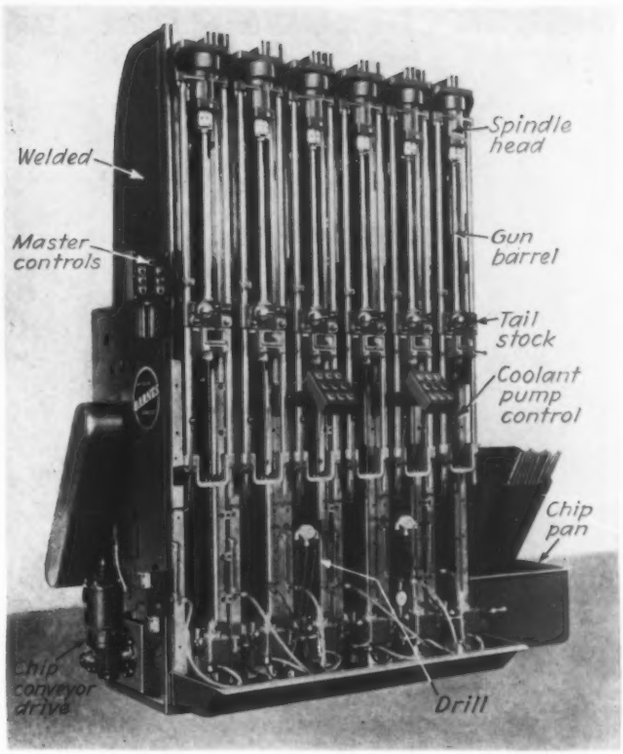
Gun barrels are held at upper end in spring-actuated chuck and supported at the other end on a ball-bearing spring-mounted center, which is mounted in retractable quill. Quill is raised or lowered with rack and pinion by turning hand lever when it is at right angles to its shaft. When pulled out as shown, cam locks the spindle. Tailstock and spindle head are connected by two ground alloy steel rods. Louis Allis cartridge-type motor drives spindle through V-belts and fits spindle head casting, entire assembly being slidably mounted in opposed vee ways. Steel pin with Stellite on the tip (instead of thrust bearing) releases chuck upon return to top position.

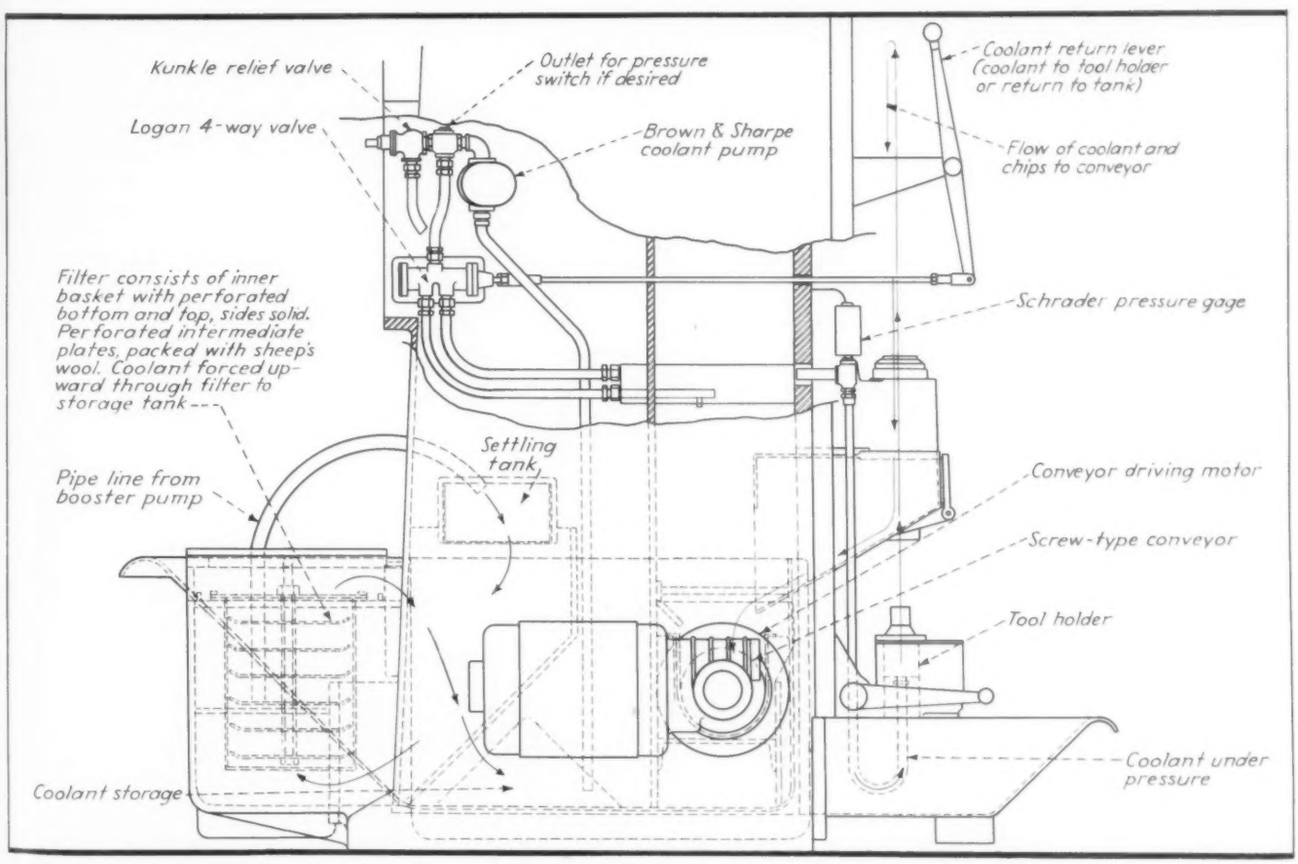
Flexible metal hose feeds coolant under pressure to hollow drill. Drill is held stationary in the tool holder by friction block as gun barrel revolves and feeds downward. When drill becomes dull or sticks so that resistance of friction block is exceeded, the drill turns slightly in its socket and a limit switch is tripped stopping feed and spindle. Tool swings out of position as shown so drill can be withdrawn.





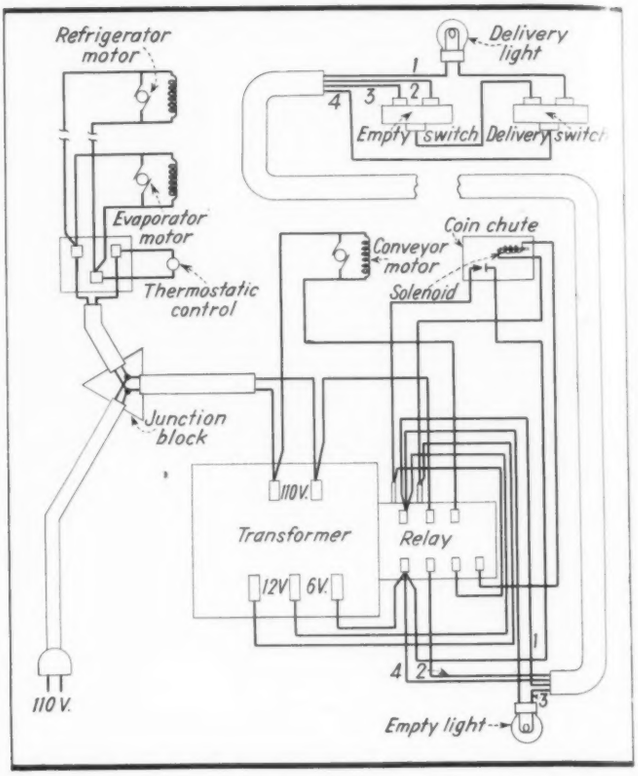
V-belt drive connects 15 hp., 1,800 r.p.m., Delco motor, to single shaft which in turn drives John S. Barnes hydraulic units and Brown & Sharpe coolant pumps through V-belts. Hydraulic units for each spindle have piston-type feed pump and gear-type rapid traverse pump. Hydraulic valves have control bar arrangement to provide automatic cycle of rapid approach, drill, rapid return and stop. Coolant pump delivers 2 g.p.m. at 750 lb. per sq. in. pressure. Drills are held stationary by friction block forced against side of drill end.




Kunkle relief valve
Outlet for pressure switch if desired
Logan 4-way valve
Brown & Sharpe coolant pump
Coolant return lever (coolant to tool holder or return to tank)
Flow of coolant and chips to conveyor
Filter consists of inner basket with perforated bottom and top, sides solid. Perforated intermediate plates, packed with sheep's wool. Coolant forced upward through filter to storage tank
Schrader pressure gage
Settling tank
Pipe line from booster pump
Conveyor driving motor
Screw-type conveyor
Tool holder
Coolant under pressure
Coolant storage

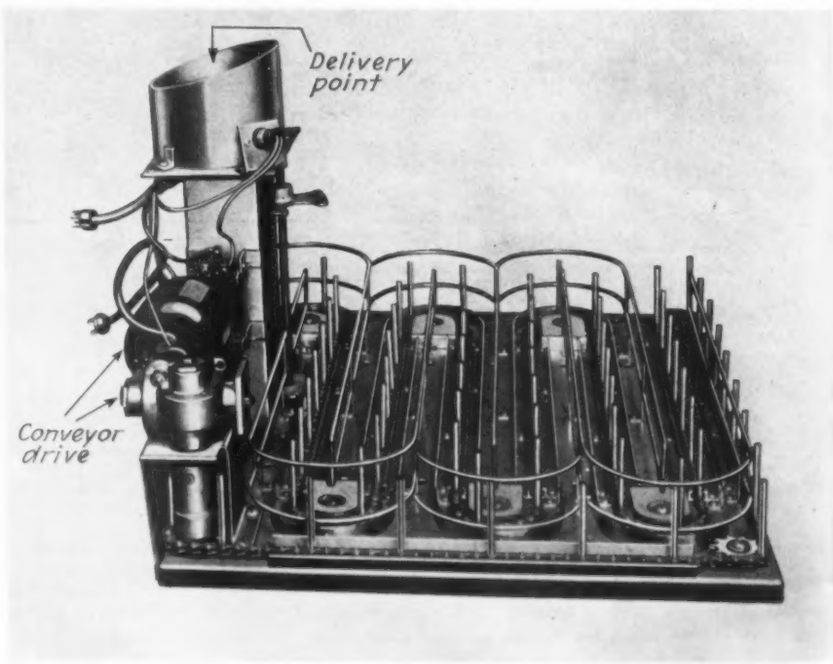
Chips and coolant drop from tailstock into chute which carries them back into screw conveyor driven by a $\frac{3}{4}$ hp. Master right-angle geared motor. Conveyor moves chips and oil to chip pan at end. Oil drains into sump in bottom of machine frame. Allis-Chalmers booster pump lifts oil to settling tray at higher level. From there oil passes through sheep's wool filter to 70 gal. storage sump ready for coolant pumps. Pump rating is 2 g.p.m., 750 pounds.

MODERN DESIGNS – Packaged Controls Speed Assembly



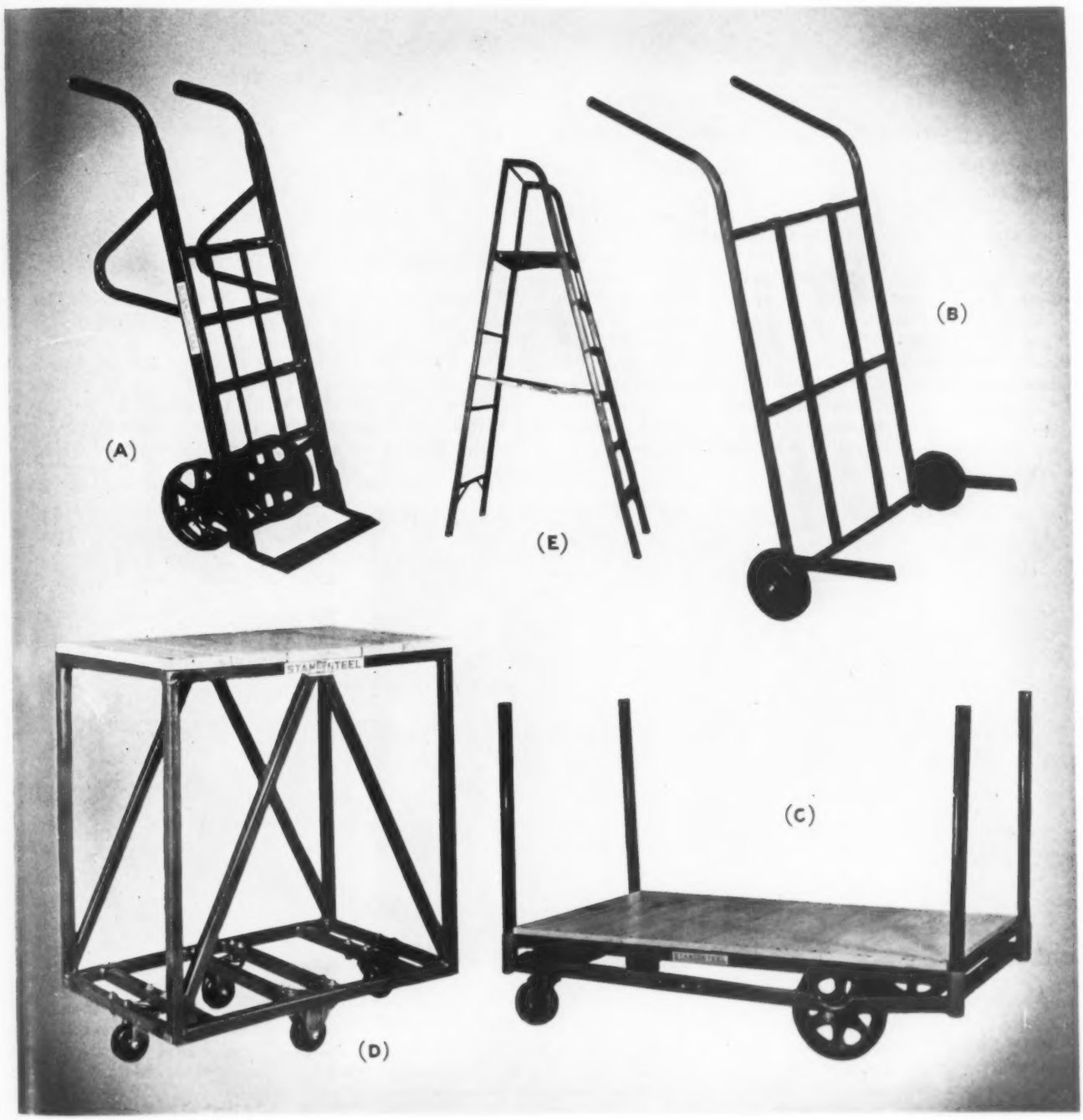
Control system of Universal Cooler vending machine is a packaged unit, designed and developed by R.B.M. Manufacturing Company so that wiring harness, switches, cord set, brackets, and other parts are delivered as a complete subassembly to be installed speedily on the line with a minimum of tools. Since unit is completely engineered, much designing and fabricating time is saved. Cabinet houses a refrigerated storage space for bottled drinks, the refrigeration unit being placed beneath the floor. Bottles rest on a conveyor which brings them underneath the opening in the top of the cabinet, one at a time, when a coin is deposited. Conveyor carries 50 bottles. Shelves in the top of the cabinet near fin-type evaporator pre-cool 16 bottles. Refrigeration is by dry forced air. Compressor and motor are mounted on rubber isolated plate.

Chain conveyor, driven by gear train and motor, is set in motion when a coin, dropped in the slot, closes the coin switch. This operates the relay which closes the conveyor circuit and starts the bottle toward delivery point. Relay also breaks the circuit to the coin solenoid, thus causing a stop to drop into the coin slot to prevent the insertion of another coin until delivery is completed. As the conveyor moves a bottle to the delivery point, the bottle tips a mercury switch lighting a delivery light to show that the machine is in operation. After bottle delivery, the conveyor trips another mercury switch which lights the "empty" light, unless another bottle is on the conveyor ready to be delivered. If another bottle is ready the mercury switches reset, releasing the relay, which in turn reenergizes the solenoid and removes the barrier from the coin slot. Entire conveyor assembly and coin control can be removed as a unit for servicing, thus the defective part can be immediately replaced and sent to factory.

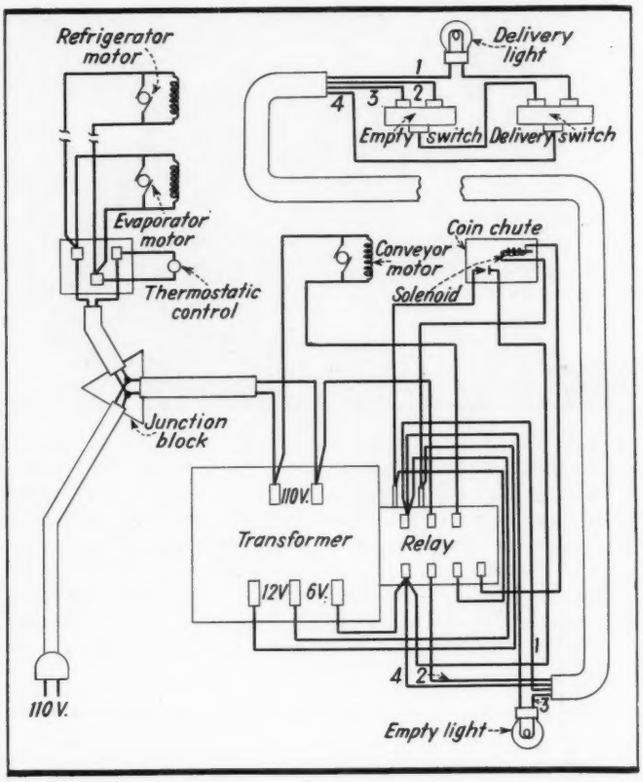


Designs for Speedier Production

Utility of welded steel tubing in design is typified by "Stan-Steel" industrial trucks and ladders, which are assemblies of standard tube shapes and sizes joined by arc or gas welding. Joints are simple. Ends are saw cut to fit square or rectangular tubes and milled to fit round tubes. A saw cut is almost always used for joining a round tube to a square tube. (A) Round tube, 2-in. dia. and 16 gage, is used for side member of this truck. End is reduced to 1½ in. for the grip. Tube is then run through dies to reduce round section to rectangular and the grip to an oval with flattened sides. Bend in the handle is simple press operation. Rests and reinforcing over wheels are simple tube bends. (B) Tote-box truck of straight welded round tubing can be readily changed to fit other size boxes. (C) Framing of this truck is $1\frac{3}{16}$x2 in. rectangular tubing. Stakes are 2 in. dia. 14 and 16 gage. Bent tubes support axle for large wheel. (D) Square and rectangular tube (16 gage, low-carbon steel) combination makes truck strong enough to carry heavy dies without reinforcing webs or heavy sections. (E) Side members of ladders have flat sides and rounded edges, are formed from ½ in., 20-gage tubing. Rounds are tubes which pass through side rails and are welded on both inside and outside of rail thus sealing against moisture accumulation in side pieces.



MODERN DESIGNS – Packaged Controls Speed Assembly



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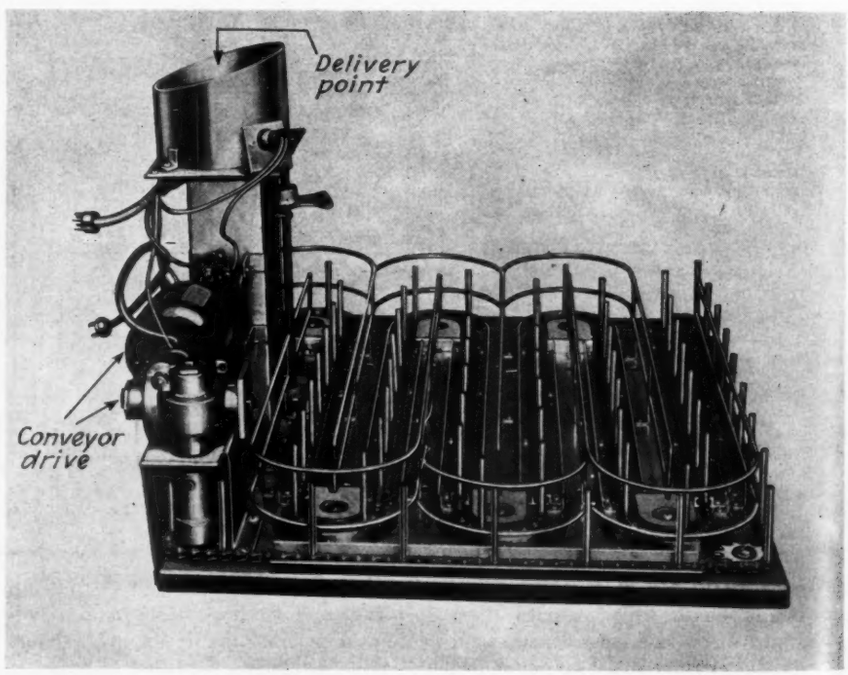

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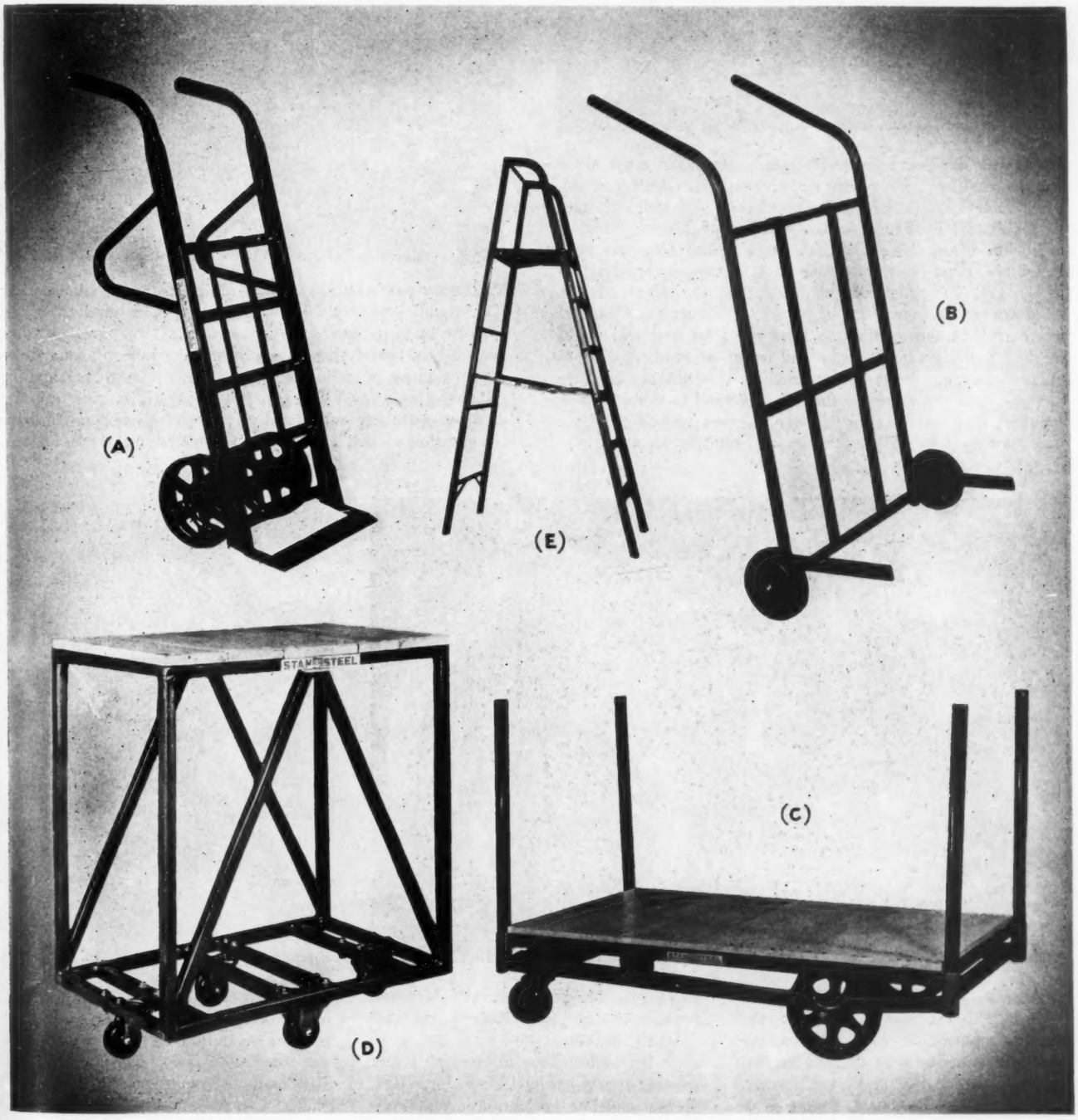
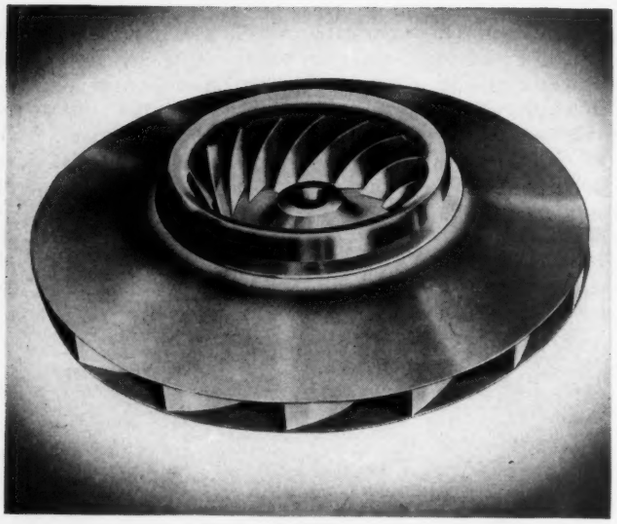


Designs for Speedier Production *(continued)*



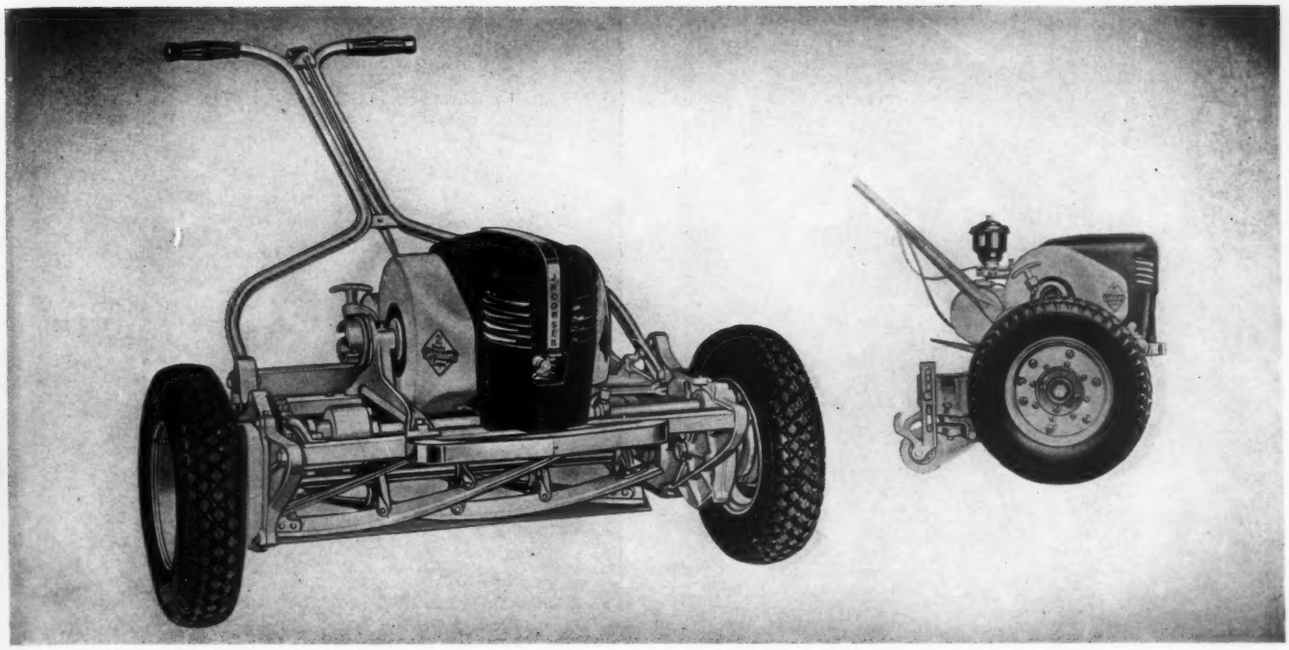
Impeller of Trane turbo-vacuum compressor must withstand centrifugal forces due to 3,600 r.p.m. rotating speed, must have smooth gas passages, must be made of non-corrosive materials to prevent dynamic unbalance caused by corrosion effects. Side plate has large opening for gas inlet which also must be sealed at the edge to prevent recirculation of the gas. To reduce weight of impeller the inlet and side plate are made of one sheet of red brass. Reversing the metal upon itself at the opening to form the inlet and seal could be done with dies but the cost and length of time required to make them was prohibitive. A method of spinning the plate to shape and reversing the metal upon itself to the accuracy required and which required only low-cost spinning chucks was developed by Milwaukee Metal Spinning Company.

Plastic coatings are being applied to parts, such as car door handles of cast iron and steel wrench handles, to get smooth surfaces and colorful finishes at comparatively low cost. Floor outlet shown was formerly made of four brass sand castings, machined and polished. Redesign at right by Gilbert Rhode for Fibre Conduit Company is zinc, die-cast in three parts and coated with Tenite by American Insulator Corporation. Much machining and polishing is eliminated.

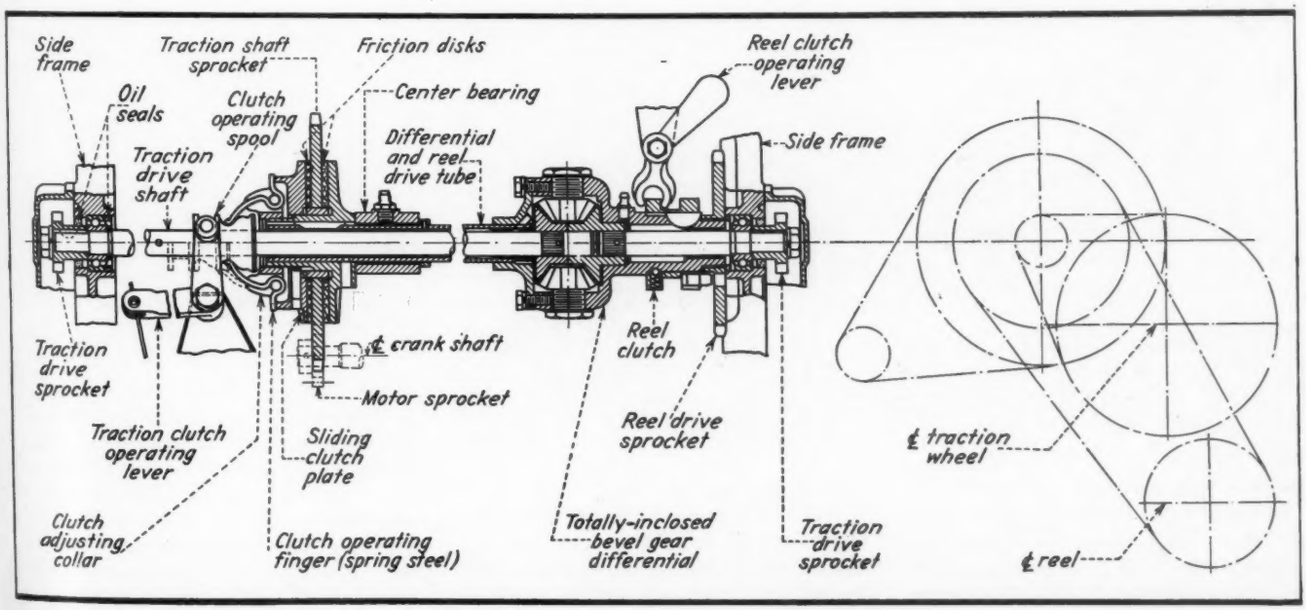
Original design of liquid server made by Federal Tool Corporation consisted of a plastic cap to which was fastened, with four rivets, a stamped handle, a stainless steel slide and a coil spring. New design by Barnes & Reinecke is molded of Tenite in several colors and consists of only two plastic parts with a small stainless steel coil spring to close the slide. Thus all stamping and riveting operations have been eliminated. Spring hooks on projection in moldings.

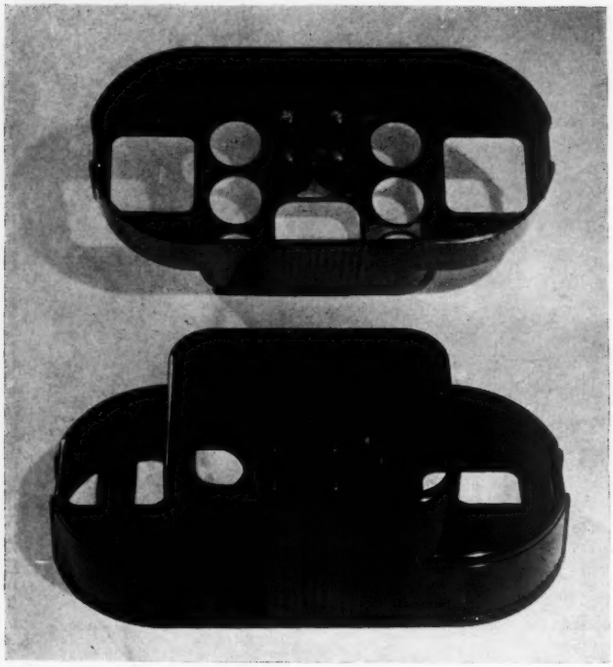
Laminated plastic dials for Ashcroft gages, replace brass or aluminum. White dial face with jet black numerals is sandwiched between layers of clear plastic; it can be kept clean readily, will not corrode or crack. Cover of gage is also made of clear plastic instead of glass.

Dual Drive for Lawn Mower

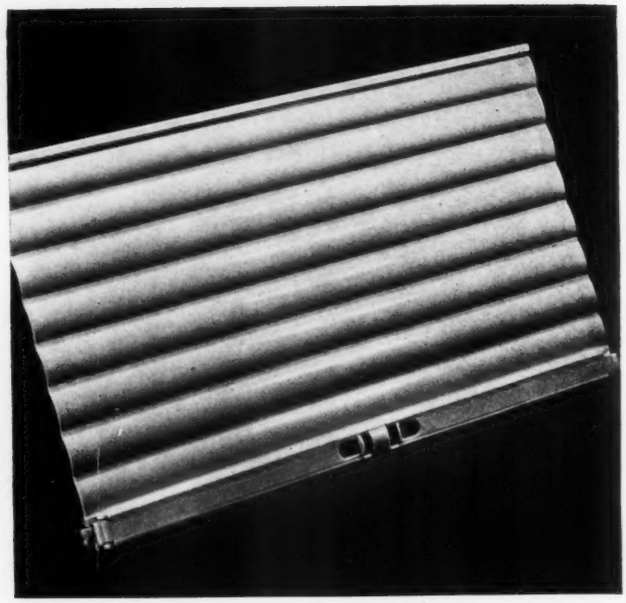


Two separate drives, each with its own independently operated clutch, are arranged about a common drive shaft on the Jacobsen Lawn King which is powered by a 1 hp. 2-cycle horizontal engine. Traction shaft sprocket is chain-driven. Sprocket serves as the driving plate of the traction clutch, power being transmitted through a friction disk on each side of the sprocket. The clutch itself is actuated by means of a spool engaging two spring steel fingers which provide resilient engagement of the sliding clutch plate. This eliminates any need for critical adjustment as would be the case with solid levers, according to Einar Jacobsen, vice-president. The stationary clutch plate is keyed to a drive tube which transmits the torque to the differential case and thence through bevel gears to the traction shaft which rotates inside the tube. This shaft is divided into two parts extending to each side of the mower from the differential. The far end of each is mounted on inclosed ball bearings in the mower side frames. The final drive to the traction wheels is through sprockets and chains, all inclosed and operating in an oil bath. The reel drive sprocket and clutch are mounted integrally with the differential case. The sprocket normally floats on a bronze bearing on the differential case when the clutch is disengaged. A sliding collar, keyed to the differential case and having driving pins to engage in holes in the reel sprocket, provides the means of transmitting the drive to the sprocket and thence by chain to the cutter reel. Differential gears and other parts are die-cast Zamac No. 3. Frame and pneumatic tired wheels are assembled of electric cast iron parts. Engine has oil bath cleaner and air vane-type governor operated from fan blast.

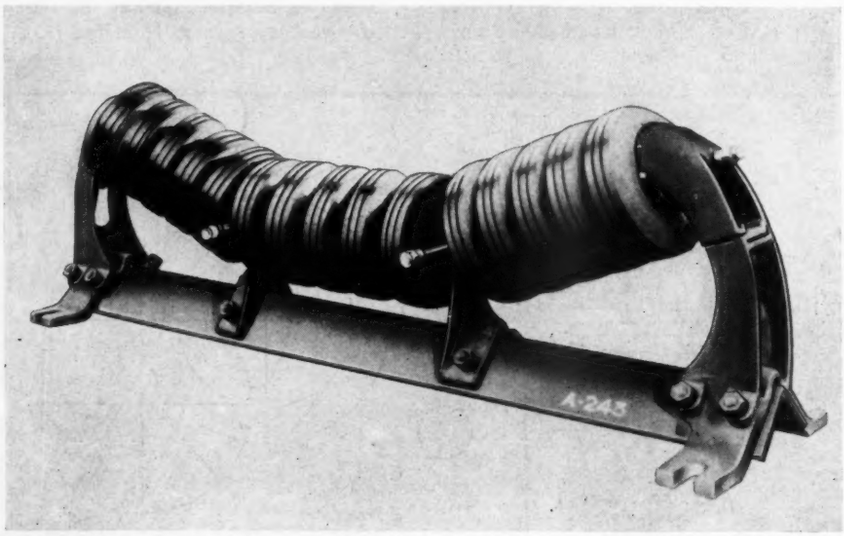




One of largest moldings made of a thermosetting plastic to date (20 in. long x $9\frac{3}{16}$ in. wide) is the Porto-Server molded of phenolic resin by Chicago Molded Products Corporation. Strength, alcohol and water resistance, were required. Parts weigh about 6 lb.; molds weigh about 2,300 lb. and cost about $7,000 each. Fluted sections and separately molded handles are painted in light shade to contrast with walnut or ebony black finish of the large molding. Same mold can be used for Porto-Baradio, Stewart-Warner radio being placed in rectangular cut-out in front of molding. Radio is shielded on top with papier-mache.



Window shades are molded of Tenite by Eclipse Moulding Products Company for Greyhound Management Company buses. Weighing approximately four lb., this shade represents one of the largest single units molded of a thermo-plastic material. Shade material had to be translucent enough to admit a soft light and yet eliminate glare, and also had to be light in weight, stable in characteristics, tough enough to withstand wear, and of attractive appearance. The mold is made so that by simple changes it can accommodate three sizes of shade: 22x20 in., 31x20 in., $33\frac{15}{16}$x20 in. by $\frac{1}{8}$ in. to $\pm$ 0.010 in. tolerances. Retainer and latch strips are molded separately of same material. Fluted cross-section provides flexibility and serves to hold shade firmly in slides, thus eliminating noise due to rattling of one part against another.



Pneumatic rollers, designed to replace steel roller with solid rubber cover for carries at points on belt conveyors subjected to shock or impact, are made up of a series of 6 in. diameter rubber "tires" mounted on a steel hub in which bearings are housed. Shafts and bearings are pressure lubricated. Roller units have thick treads, and are permanently sealed against loss of air.

RANDOM JOTTINGS ABOUT NEW DEVELOPMENTS

PINCH ON METALS is causing return to previously used materials: Rail car makers following ship builders in the swing back to use of wood instead of steel. Demand for freight cars and not sufficient priority on steel is causing the return to wood construction. Zinc alloy parts in washing machine wringers are being replaced with cast iron. Agitators made of assembled porcelain enameled steel stampings are undergoing experiment. Glass tanks are replacing zinc tanks on kerosene heaters.

New uses for plastics include: Artus milling cutter spacers in thicknesses of 0.001 to 0.0075 in., each thickness being of a different color for ready identification; Plaskon plastic for Bassick casters in colors to match furniture; Curved Lucite rod on end of flashlight case with small magnet in tip for finding and picking up small parts in dark corners.

CENTRIFUGAL GOVERNORS

Analysis of Properties With Design Procedure

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DESIGNED to maintain automatically constant speeds of prime movers, regardless of load demands, centrifugal governors are quite simple in operation. A centrifugal force which acts on rotating weights is balanced by known forces, usually gravity for low speeds and springs for high speeds. Any change in the speed of the unit being governed will vary this centrifugal force. For equilibrium to be maintained, the weights must assume a new position in response to any change of speed. This movement is used to vary the energy input to the machine being governed thus restoring its speed to the normal value. From this it is seen that a governor has two functions; to measure the prime mover speed and to vary the energy supply.

The properties of a governor are naturally dependent upon its design. Hence, before taking up the actual design procedure, it will be helpful to consider in some detail these properties and the way in which they can be measured. As outlined here, these properties agree with those given in the A.S.M.E. Power Test Code for Speed Responsive Governors.

PERCENT SPEED REGULATION is the total speed variation of the machine expressed as a percentage of the mean or average speed of the unit. This property may be measured for two conditions of operation:

Condition (*A*)—The change of speed which occurs with a load change.

Condition (*B*)—The departure from constant speed which occurs with constant load and constant operating conditions of the prime mover.

The regulation for which the governor is to be designed will depend upon the use of the driven machinery or apparatus. If the regulation becomes extremely small the governor is said to be isochronous. Under this condition the weights do not have a definite position for each speed, hence they will alternately move rapidly between the extreme positions, and the prime mover will experience sudden speed changes, known as "hunting."

In general, centrifugal governors have a regulation of 2 to 12 percent; those operated in conjunction with an oil relay have a regulation of about half this amount. For Condition (*B*) the departure from a constant speed with constant load and operating conditions is small; the maximum value being about ¼ percent. The regulation for this latter condition is more dependent upon the size of the rotating parts or a flywheel, than upon the governor; since the action is too rapid and frequent for governor control.

When N_a = r.p.m. of machine at high speed divided by 1,000
N_b = r.p.m. of machine at low speed divided by 1,000

the formula for determining the percent of speed regulation R is

$$R = \frac{N_a - N_b}{(N_a + N_b)/2} \times 100$$

$$= \frac{2(N_a - N_b)}{N_a + N_b} \times 100 \qquad (1)$$

The percentage regulation of a given unit can be determined by test. For Condition (*A*) the unit is operated at various loads, then after conditions have become steady, the exact speed is noted. A curve can then be plotted of speed against load, which will show any deviation from the desired straight line relationship. The regulation is usually based upon the two extremes of loading, that is, upon the no-load speed and full-load speed. For Condition (*B*) the extremes of speed are found by means of a sensitive tachometer or oscillograph. Naturally, the regulation for this condition will be closer for a rotating machine than for a reciprocating one, since the energy input is more uniform.

PERCENT SPEED ADJUSTMENT is the percentage of the nominal or normal speed of the unit at which the governor will operate satisfactorily without exceeding acceptable values of regulation. For example, a turbine may be specified to operate at 2,000 r.p.m. with a ±10 percent speed adjustment. This means that the governor should be adjustable so that the turbine will run satisfactorily at any speed between 1,800 and 2,200 r.p.m. This can be done by adjusting the tension in the outside spring.

SENSITIVENESS is a measure of the minimum change in speed at any governor position which will cause a movement of the governor mechanism. This property is measured as a percentage of the average or mean speed, hence can be calculated by Equation (1). Sensitiveness is a measure of the amount of friction and lost motion in the governor mechanism, and depends upon:

1. Design, that is, the number and type of pivots or working joints.
2. Lubrication of the moving parts.
3. Amount of vibration of the governor.
4. Forces transmitted to the governor through the sleeve.

Sensitiveness can be measured by slowly changing the load on the prime mover and observing the speed change required to cause the governor mechanism to change its position.

If there is too much lost motion or friction, no motion of the governor will occur until the speed change is large, and the mechanism will then move considerably after it does start. The result will be large swings in the speed, giving an undesirable hunting condition.

A governor with a small regulation will be more sensitive than one with a large regulation, as the movement of the mechanism will be greater for a given speed change.

RAPIDITY is a measure of the speed with which the mechanism of the governor adjusts the valves in response to a sudden load change. This property includes the speed variations which occur with sudden load changes and the time required for the prime mover to return to its normal speed.

In order to determine the rapidity it is necessary to use a recording tachometer or oscillograph which will record the speed of the prime mover from the instant the load is changed until the speed is again normal.

A governor with a small regulation will have a relatively small motion for a given speed change, so that the action of the governor in restoring the prime mover to the normal speed is rapid.

STABILITY. For each given speed of the prime mover there should be a definite position of the governor mechanism. If this is so, the governor is said to be stable. However, if the mechanism assumes a number of positions for a

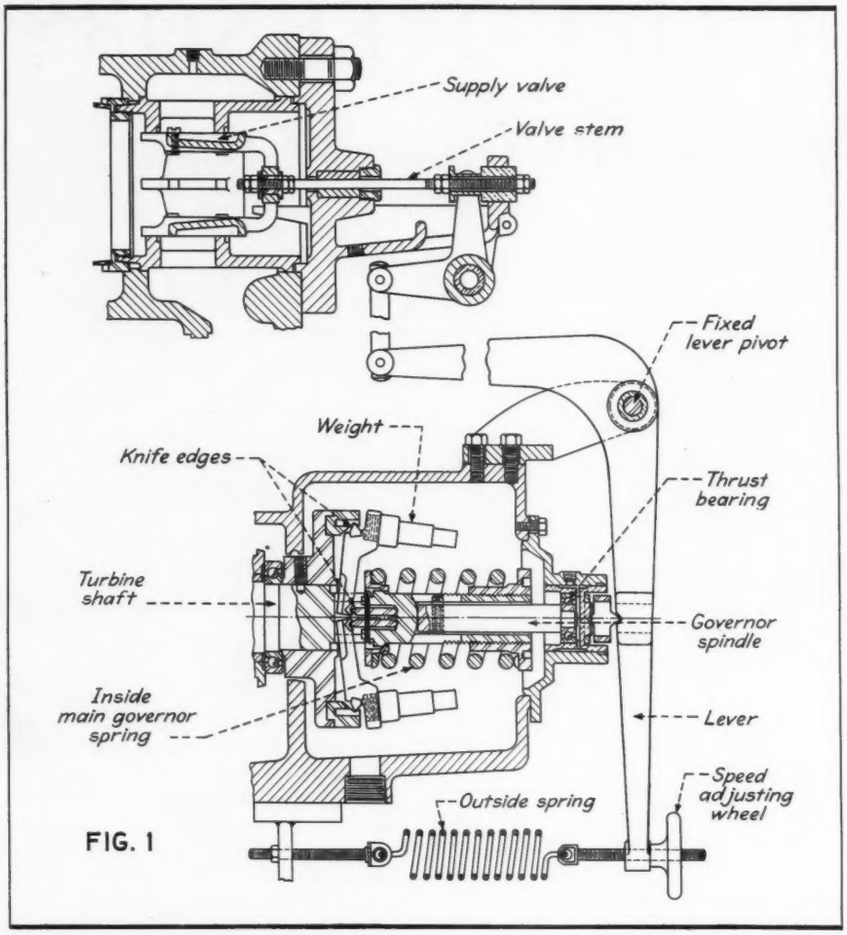


Fig. 1—Typical centrifugal governor with lever arms and outside spring for governing a steam turbine. (De Laval Steam Turbine Company)

given speed, the governor is said to be unstable and tends to hunt. A stable governor generally has a low sensitivity and a large regulation, and is also rapid in action.

GOVERNING FORCE or STRENGTH is the regulating force of the governor, or the force available to operate the valves. Since it is a property of the governor, this force is always measured at the governor sleeve rather than at the valve.

If the speed of the prime mover is constant there is no force exerted on the valve levers, as the centrifugal force on the weights is balanced by the spring load or by the force of gravity. If, however, the governor sleeve is held fixed while the speed is changed 1 percent, the force exerted on the sleeve is known as the strength, or ability to overcome unbalanced forces and friction. This property should be determined for both the inner and outer positions of the weights as the strengths will differ for the two positions.

The governor strength for a 1 percent speed change can be determined by operating the prime mover at no load and 99.5 percent of the normal speed. The linkage between the governor and valve is adjusted so that the weights will be in their high speed position. If the supply valve is then moved until the prime mover speed is 100.5 percent of the normal and the governor sleeve held fixed, the resulting force exerted at the sleeve will be the strength. This test should be repeated with the weights in their low speed position.

The strength can be calculated for any given speed, N, as it is the difference in spring loads for a 1 percent speed change. In order to derive this equation let

V = volume of weights, cu.in.
d = dia. through center of gravity of weights, in.
G = moment arm of center of gravity above the pivot point, in.
H = moment arm of spring load from pivot point, in.
Q = lever ratio = G/H
N = speed in 1,000 r.p.m., r.p.m./1,000
k = weight constant, lb. = $4.025\ VdQ$
L = spring load, lb.

Initial load on spring = $4.025\ VdQ\ (0.995\,N)^2$
$= k\ (0.995\,N)^2$

Final load on spring, assuming that the position of the mechanism is not changed

$= k\ (1.005\,N)^2$

Available force = $k\,[(1.005\,N)^2 - (0.995\,N)^2]$
$= 0.02k\,N^2 = 0.02L$ (2)

It is evident from Equation (2) that the strength for a given speed can be increased by increasing the size of the weights, the diameter to their center of gravity, or the lever ratio. Equation (2) does not include frictional effects in the governor itself; hence the equation will not check the test values exactly. The strength is limited by the size of the governor which in turn is limited by stress considerations and the size of the prime mover.

WORK CAPACITY for a 1 percent speed change is the arithmetical mean of the governor forces at the inner and at the outer positions of the weights for a 1 percent speed change multiplied by the arithmetical mean of the two corresponding sleeve travels for a 1 percent speed change.

Any factor which will increase the strength will in turn increase the work capacity. The work capacity will also be increased by a longer travel for a given regulation, or smaller regulation for a given travel.

Design Procedure

A sectional drawing of a steam turbine governor with its lever arms and outside spring is shown in Fig. 1 to illustrate a typical centrifugal governor.

CENTRIFUGAL FORCE. If the density of steel is taken as 0.283 lb. per cu. in., the centrifugal force F in lb. exerted by a particle of weight w lb. rotating about the center line at a radius r in. or a diameter d in., with an angular velocity of ω radians per sec., is

$$F = mr\omega^2 = \frac{wr}{g12}\left(\frac{2\pi\,1{,}000\,N}{60}\right)^2$$

or $F = 8.05\ V\,r\,N^2 = 4.025\ V\,d\,N^2$ (3)

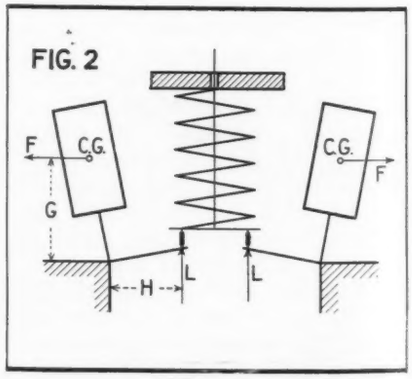


Fig. 2—Schematic diagram of a typical spring loaded centrifugal governor showing the forces in the system

The schematic sketch, Fig. 2, of a typical spring loaded centrifugal governor shows the forces acting. An analysis of these forces shows that for any position

$$L = \frac{FG}{H} = FQ = 4.025\ V\ d\ N^2 Q \qquad (4)$$

where V is the total volume of two weights. Since for any given position of a particular governor V, d and Q are always the same, Equation (4) may be written.

$$L = k\ N^2$$

The factor k is a function of the moment of the centrifugal force as applied at the spring seat.

In terms of the spring load for the final or outer weight position L_t in lb., the spring load for the initial or inner weight position L_o in lb., and the sleeve travel T in in.; the scale S of the governor spring in lb./in. is given by

$$S = \frac{L_t - L_o}{T} \qquad (5)$$

It can be shown (see pages 448-449 of the first edition of *Mechanics of Machinery* by Ham & Crane) that it is not correct to find the centrifugal force moment by assuming the mass of the weights and lever arms as concentrated at their centers of gravity. Instead, these items should be broken down into small simple shapes, and the moment found for each separately. These moments may then be summed up to obtain the total moment for any position of the mechanism. The correct method of obtaining this moment would be to employ integration, but it is usually impractical. The need for breaking up the masses into small parts increases when the line through the pivot and center of gravity of the whole mass makes a large angle with the center line of rotation, and when the distance between this center of gravity and the pivot point is large, that is, for "long" weights.

GOVERNOR. To illustrate the design procedure simply it will be assumed, although incorrectly as just noted, that the mass of the weights is concentrated at their centers of gravity as shown in Fig. 2, and that the weight of the arms is neglected. The nominal speed N, the desired percentage regulation R and the travel of the sleeve T are given. The volume of the two weights V is found by trial to give the desired strength, and the dimensions of the mechanism assumed with regard to the overall size of the governor. From these preliminary values a layout, which should be several times full size for accuracy, and a table as shown in Fig. 3 are made.

The total travel T is divided into a number of equal steps, and the corresponding positions of the center of gravity located as shown. The values of H, G and d are listed in the table for the various positions. From these the lever ratios Q and the factors k can be obtained.

Knowing the nominal speed N and the percent regulation R, the values of N_o and N_t can then be determined and entered in the table. The values of centrifugal force F, and spring load L, can then be calculated using the spring loads at the end positions. The required spring scale can be calculated by the Equation (5). It should be noted that these spring loads and this spring scale are really "equivalent" as will be explained later.

Having determined the spring scale S, which is constant, the end spring loads L_t and L_o, and the deflection of the spring at the various positions, the intermediate spring loads can be obtained. From these intermediate spring loads the corresponding centrifugal forces and speeds are found, thus completing the table.

In the procedure as outlined, the size of the weights and lever ratio may be varied until desired spring load condition is met.

OPERATING LEVERAGE. A sketch of the leverage connecting the governor with the energy supply to the prime mover is shown diagrammatically in Fig. 4. As mentioned previously, the values of spring load and spring scale found in the procedure described are "equivalent" since they represent the outside spring load L_1 and the outside spring scale S_1, combined with load L_2 and

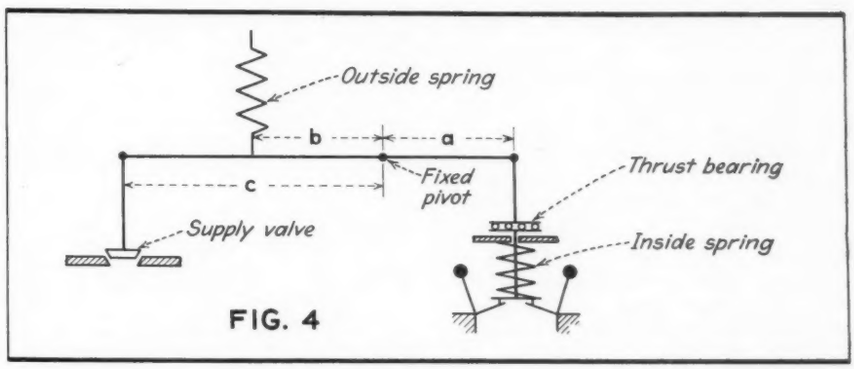


FIG. 4

Fig. 4—Diagrammatic sketch of the leverage system connecting the centrifugal governor with the energy supply valve for the prime mover

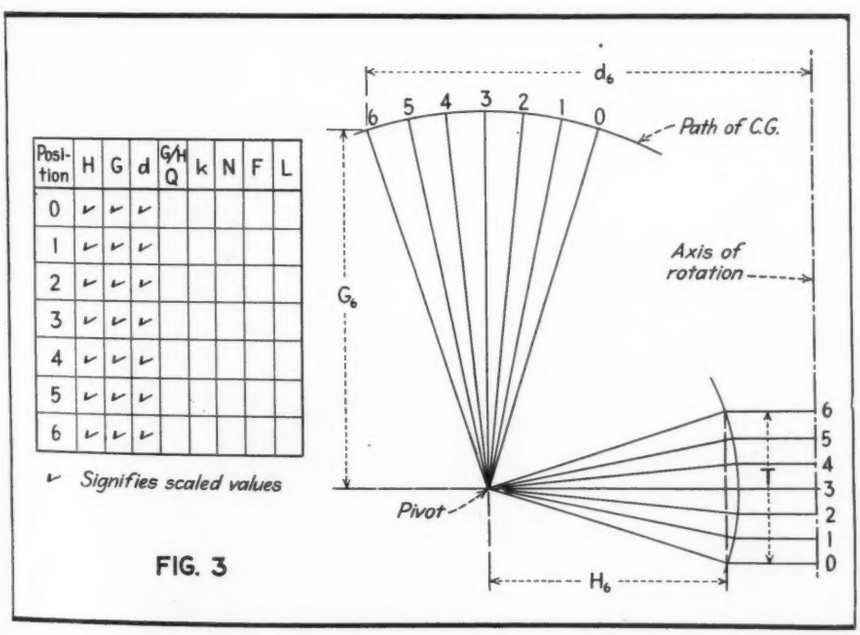


FIG. 3

Fig. 3—Graphical construction for obtaining values of moment arm of spring load from pivot point, moment arm of center of gravity above the pivot point, and the diameter of the path of the center of gravity

the scale S_2 of the main governor spring.

Where T is the travel of the governor stem, it is seen from Fig. 4 that the travel of the supply valve is given by $T \times (c/a)$, and the deflection of the outside spring by $T \times (b/a)$. All forces and scales are referred back to the governor, so that expressions can be derived for the equivalent spring load E_L in lb., and the equivalent spring scale E_S in lb./in., with both terms referred to the governor sleeve, so that

$$E_L = L_2 + L_1 \times (b/a) \qquad (6)$$

$$E_S = S_2 + S_1 \times (b/a)^2 \qquad (7)$$

The equivalent spring scale E_S and the equivalent spring load E_L must be divided between the outside and inside springs in accordance with Equations (6) and (7). It is unwise to put too much load on the governor thrust bearing by making the outside spring load or scale too large.

SPEED ADJUSTMENT. It may be desirable to have a certain range of speed through which the unit will act satisfactorily, that is, speed adjustment. This may be obtained, within limits, by altering the initial load on the outside spring.

For example, suppose that the unit is to operate with a nominal speed 10 percent greater or less than its usual value N without having its regulation exceed the limits of 2 to 10 percent. For a given mechanism and weights, curves like those shown in Fig. 5 can be plotted. With low speed N_b and high speed N_a being the nominal speeds for the given adjustment plus or minus one half the regulation R, E_{Lo} and E_{Li} being the equivalent spring loads at the initial or inner weight position and the final or outer weight position respectively, also k_o and k_i being the weight constants at the initial and final weight positions, the spring load curves can be found from

$$E_{Lo} = k_o N_b^2, \qquad E_{Li} = k_i N_a^2$$

The values thus found are plotted at the nominal speed for the given adjustment. The equivalent spring scale is plotted from the load points found by the equation

$$E_S = \frac{E_{Li} - E_{Lo}}{T}$$

For a given mechanism and set of springs, there can be only one spring scale. This is represented on the diagram by a horizontal dotted line drawn between $0.9N$ and $1.1N$. This line should not cross either of the equivalent spring scale curves as they represent the limits of the regulation range. After this equivalent spring scale has been established, the corresponding points on the E_{Lo} and E_{Li} curves are found. These curves are also shown dotted on the figure. There is no reason for attempting to find any points other than the end points, as they are all that are needed for designing.

Having obtained E_S, E_{Lo} for 2 and 10 percent regulation and E_{Li} for 2 percent regulation from the curves, the spring scales and loads for the inside and outside springs can be found by the Equations (6) and (7). It is desirable to have the initial outside spring load zero or nearly so for $0.9N$ and the 10 percent regulation, and to keep the outside spring scale as low as possible so as to reduce the load on the governor thrust bearing. Having found the loads and scales of both springs, they can now be designed to suit space and stress considerations.

CHARACTERISTIC CURVES. If the centrifugal force acting on the weights is plotted against the radial position of their center of gravity as shown in Fig. 6, more information concerning the governor action is disclosed. Referring to this figure, the curve *bma* is the theoretical curve for a typical governor. There will be a certain amount of friction and lost motion in the mechanism so that the actual curves will be displaced somewhat from the theoretical. These are shown as dotted lines in the figure, the upper line representing the actual curve obtained when the weights are moving outward and the lower line for the weights moving inward.

The radial lines *oa*, *on* and *ob'* are lines of various constant speeds since

$$F = 8.05\, V\, r\, N^2 = constant \times r$$

If these radial lines coincide with the characteristic curve for short distances, the weights may assume several positions for a given speed and the governor is unstable. If the curve should be a straight line which if extended would pass through the origin O the governor would be isochronous. Hence, the larger the angle which the curve makes with the radial lines, the more stable the governor.

It is shown in Trinks "*Governors, and the Governing of Prime Movers*," that the percentage regulation is given by the value of the expression

$$\frac{ab'}{aw + b'w}$$

By drawing the semi-circle *asw* and ray *omn* to *aw* and the horizontal *ns*

$$N_m = \frac{ws}{wa} N_a$$

so that if the speed at a point such as *a* is known, the speed at any other point on the curve such as *m* can be found graphically.

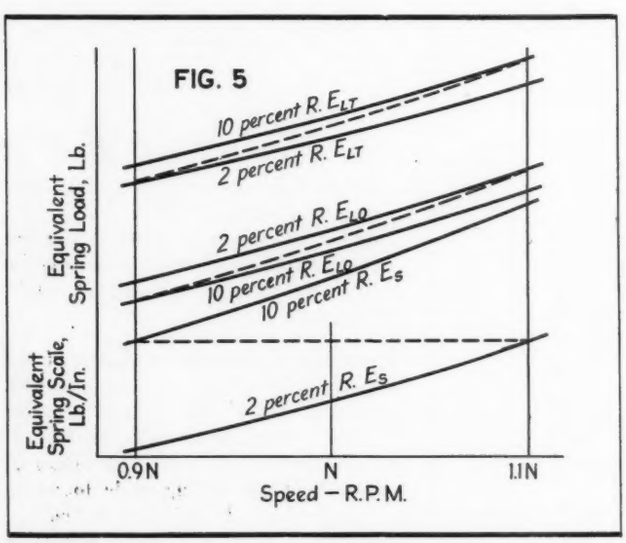


Fig. 5—Graphs for determining factors needed to calculate spring load and scale values

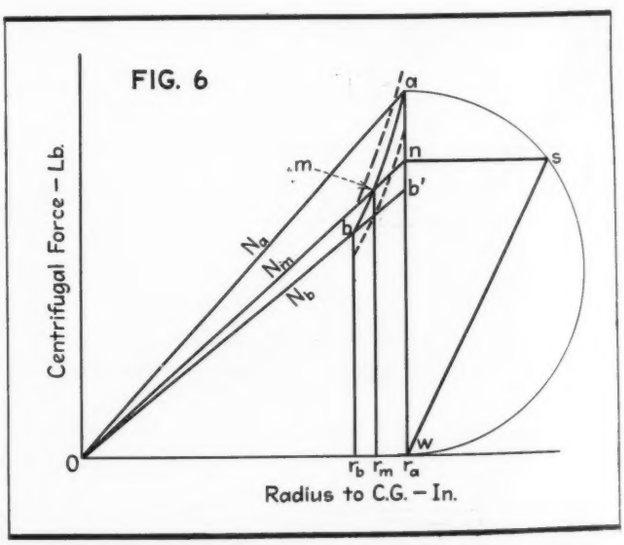
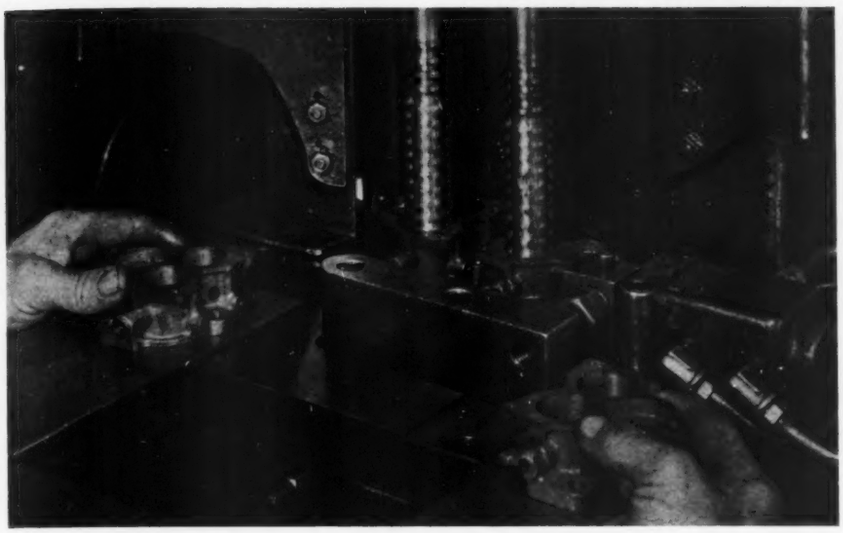
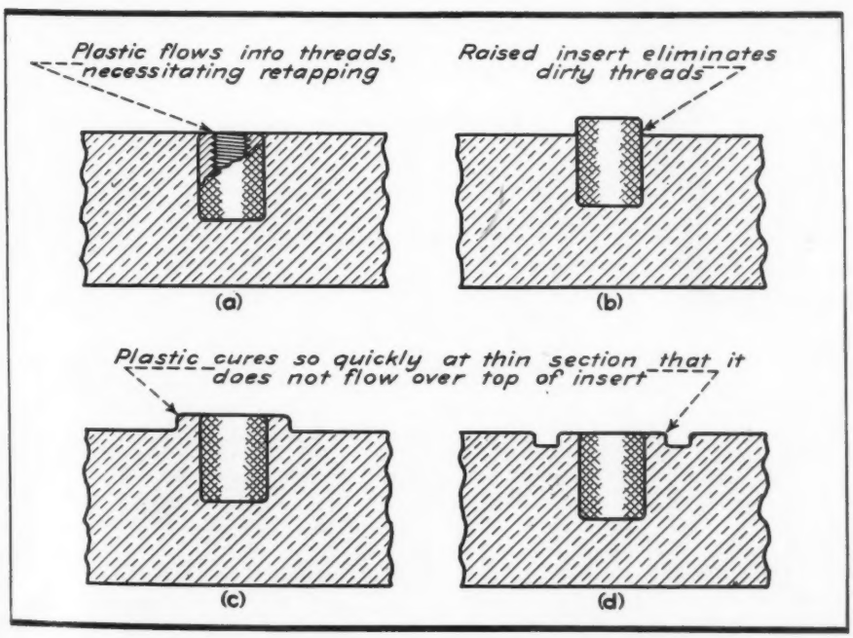


Fig. 6—Characteristic curve for determining the properties and action of a centrifugal governor

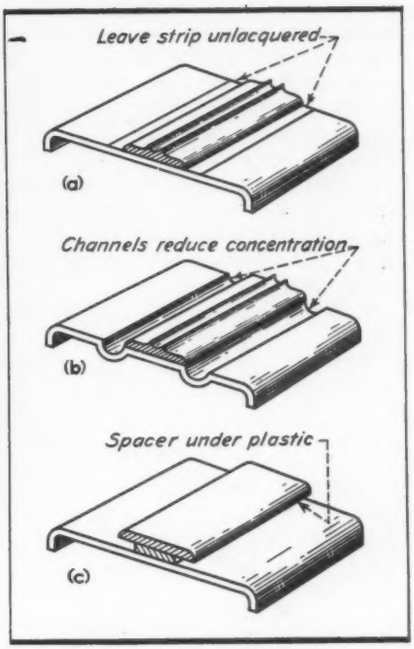
Causes and Cures



The two holes in a carburetor through which fuel mixture is distributed must be exactly alike for good performance of V-type engines. Ford engineers have specified that one hole should not be more than 0.0002 in. larger in diameter than the other. Preliminary tests showed that no matter how accurately alike two separate broaches were, the allowable variation between holes machined by them was exceeded. Required accuracy could be obtained only by specifying that the same broach be used for both holes in each carburetor throttle-body. Result is the tandem set-up shown in the above illustration.


Plastic flows into threads, necessitating retapping
Raised insert eliminates dirty threads
(a)
(b)
Plastic cures so quickly at thin section that it does not flow over top of insert
(c)
(d)

Tapped inserts in molded phenolic plastics often must be cleaned after the molding operation. Plastic is apt to flow into the threads when the top of the insert is flush with molded piece. Methods adopted by General Electric for eliminating this plastic flow are shown in (b), (c), and (d) above.



Extruded plastic molding applied to lacquered metal, such as window garnish molding and instrument panels of automobiles, resulted in changed colors, embrittlement, peeling and "dissolving" of the lacquer in a narrow zone around the molding. As the plastic aged its plasticizer evaporated and attacked the lacquer. By designing the molding and panel as shown above and by slightly changing the lacquer formula and the plasticizer, the situation has been considerably improved. Polystyrene extruded plastic, which will soon be available, may be another cure because polystyrene is not plasticized.

SEVERE TORSIONAL SHOCK loads were placed on the spindle of a brake drum truing lathe when the motor stopped. The lathe was used for turning heavy truck wheels weighing as much as 2,000 lb. The shock loads were caused by the single-thread worm in the spindle drive. Helix angle of the worm was so small that the worm locked when the spindle, in attempting to coast to a stop, reversed the drive through the worm. Cure was to change to a three-thread worm and reduce its speed.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

BEARINGS IN DIE-CASTINGS

BEARINGS in die-castings fall into three distinct classifications:

1. Holes cored or drilled in the die-casting with high accuracy, reamed or broached to accurate size with the die-casting metal serving as the bearing material. Since most die-casting alloys are too soft for heavy bearing service, this type should be used only for light loads or low speed.

2. Bushings can be cast into the die-casting as inserts. Since they are accurately located by pins in the die, at most only light broaching or reaming is required after assembly.

3. Bearings of almost any type can be pressed into holes or recesses cored in the die-casting. For accurate center distances and diameters, these cored holes also should be finish broached or reamed.

Die-casting alloys of higher melting points than the zinc alloys have greater shrinkages in cooling and, therefore, more liberal casting tolerances, and slightly more machining will be required. Some aluminum and copper alloys have bearing properties better than those of the zinc alloys.

Recesses for oil holes can be cored if they do not have undercuts. Drilling these holes may be cheaper. Porous bronze bushings should be pressed in. They have successfully been cast-in as inserts, but hot metal flowing around them is likely to close the pores and spoil the oil-feeding properties of the bushings.

Ease of replacing the bearing is often a consideration. Bushed bearings can readily be replaced. Where the die-casting alloy itself acts as the bearing, it is necessary to redrill the hole for a repair bushing or for a larger shaft size when the hole wears out-of-round. The designs shown here are through the courtesy of The New Jersey Zinc Company.

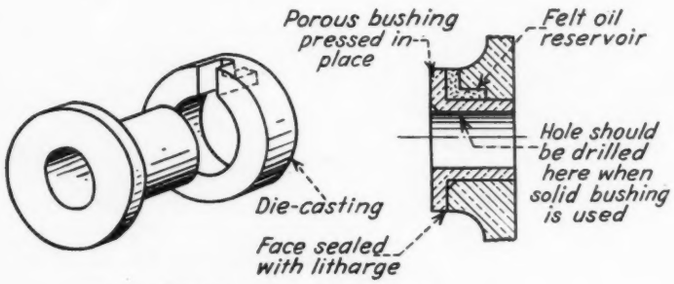

Porous bushing pressed in place
Felt oil reservoir
Hole should be drilled here when solid bushing is used
Die-casting
Face sealed with litharge

FIG. 1-CORED OIL RESERVOIR

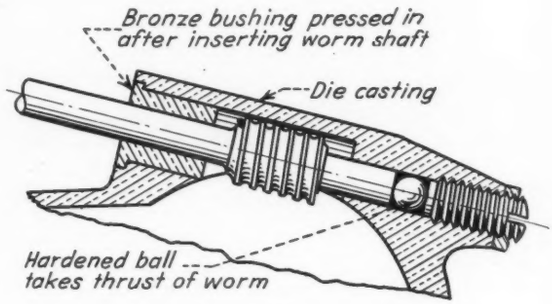


FIG. 2-WORM SHAFT MOUNTING

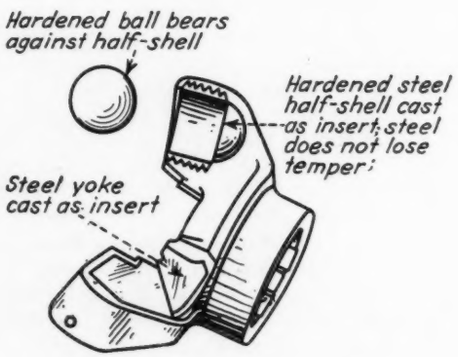

Hardened ball bears against half-shell
Hardened steel half-shell cast as insert; steel does not lose temper
Steel yoke cast as insert

FIG. 3-UNIVERSAL JOINT

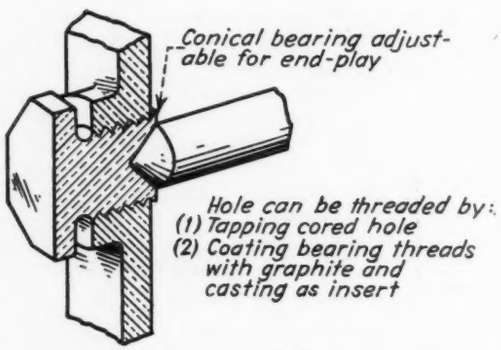

Conical bearing adjustable for end-play
Hole can be threaded by:
(1) Tapping cored hole
(2) Coating bearing threads with graphite and casting as insert

FIG. 4-ADJUSTABLE CONICAL BEARING

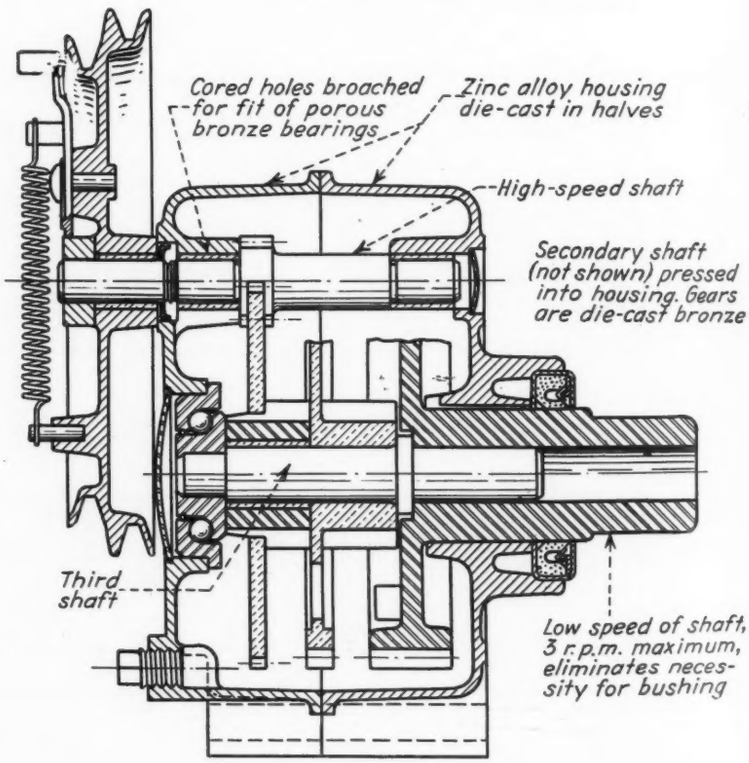

Cored holes broached for fit of porous bronze bearings
Zinc alloy housing die-cast in halves
High-speed shaft
Secondary shaft (not shown) pressed into housing. Gears are die-cast bronze
Third shaft
Low speed of shaft, 3 r.p.m. maximum, eliminates necessity for bushing

FIG. 5-GEAR REDUCER

Typical Methods for Mounting

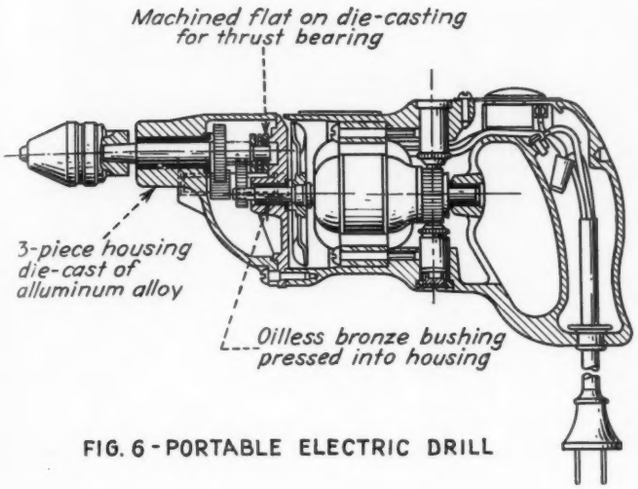

Machined flat on die-casting for thrust bearing
3-piece housing die-cast of alluminum alloy
Oilless bronze bushing pressed into housing

FIG. 6 - PORTABLE ELECTRIC DRILL

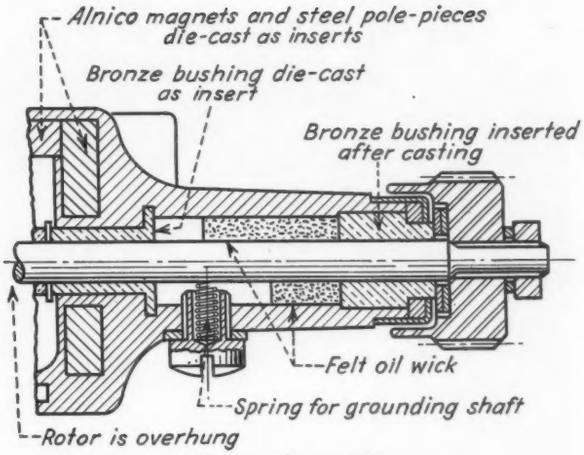

Alnico magnets and steel pole-pieces die-cast as inserts
Bronze bushing die-cast as insert
Bronze bushing inserted after casting
Felt oil wick
Spring for grounding shaft
Rotor is overhung

FIG. 7 - MAGNETO

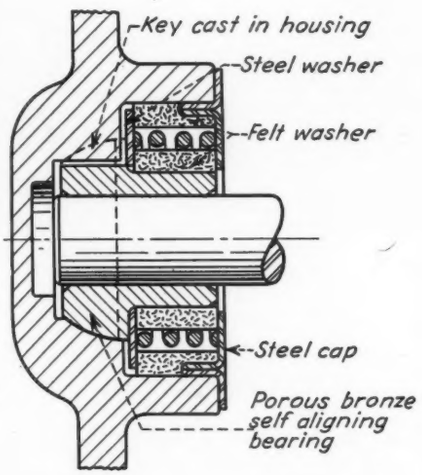


FIG. 8 - SELF-ALIGNING BEARING

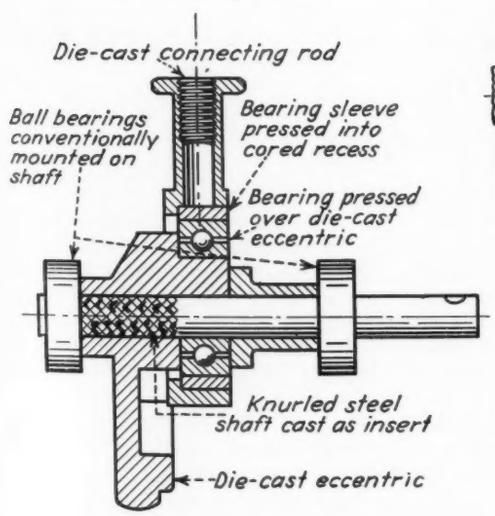

Die-cast connecting rod
Ball bearings conventionally mounted on shaft
Bearing sleeve pressed into cored recess
Bearing pressed over die-cast eccentric
Knurled steel shaft cast as insert
Die-cast eccentric

FIG. 9 - SHAFT OF LIGHT AIR COMPRESSOR

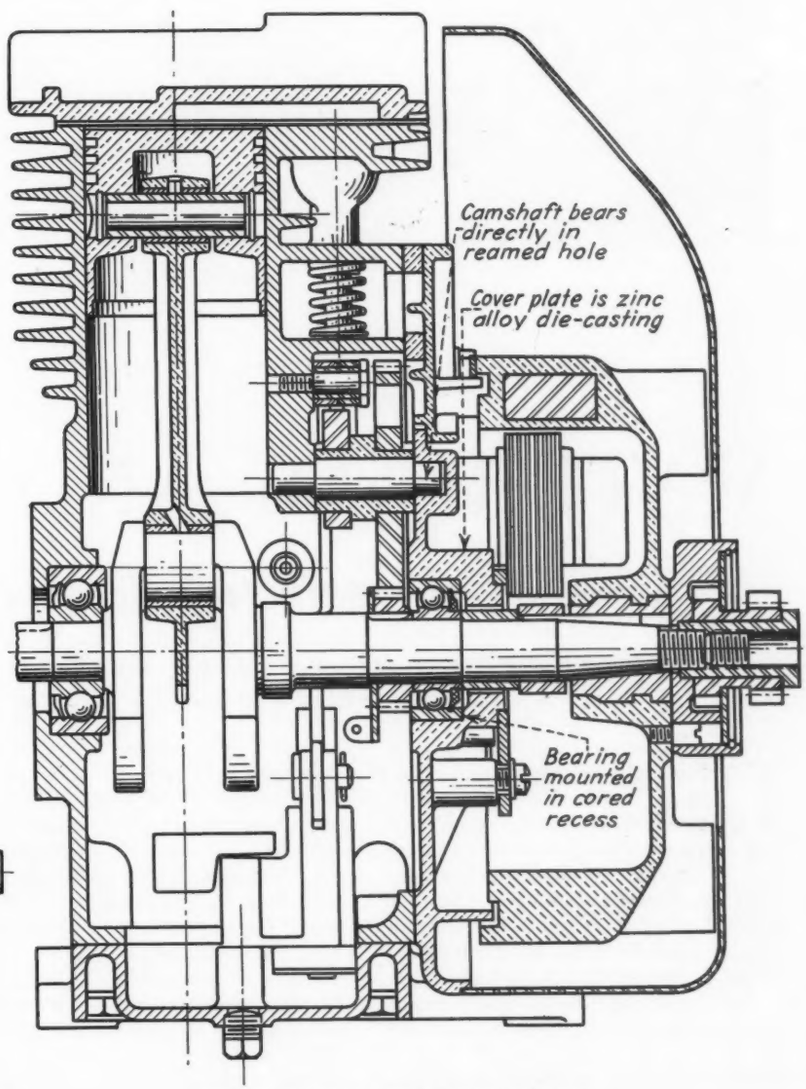
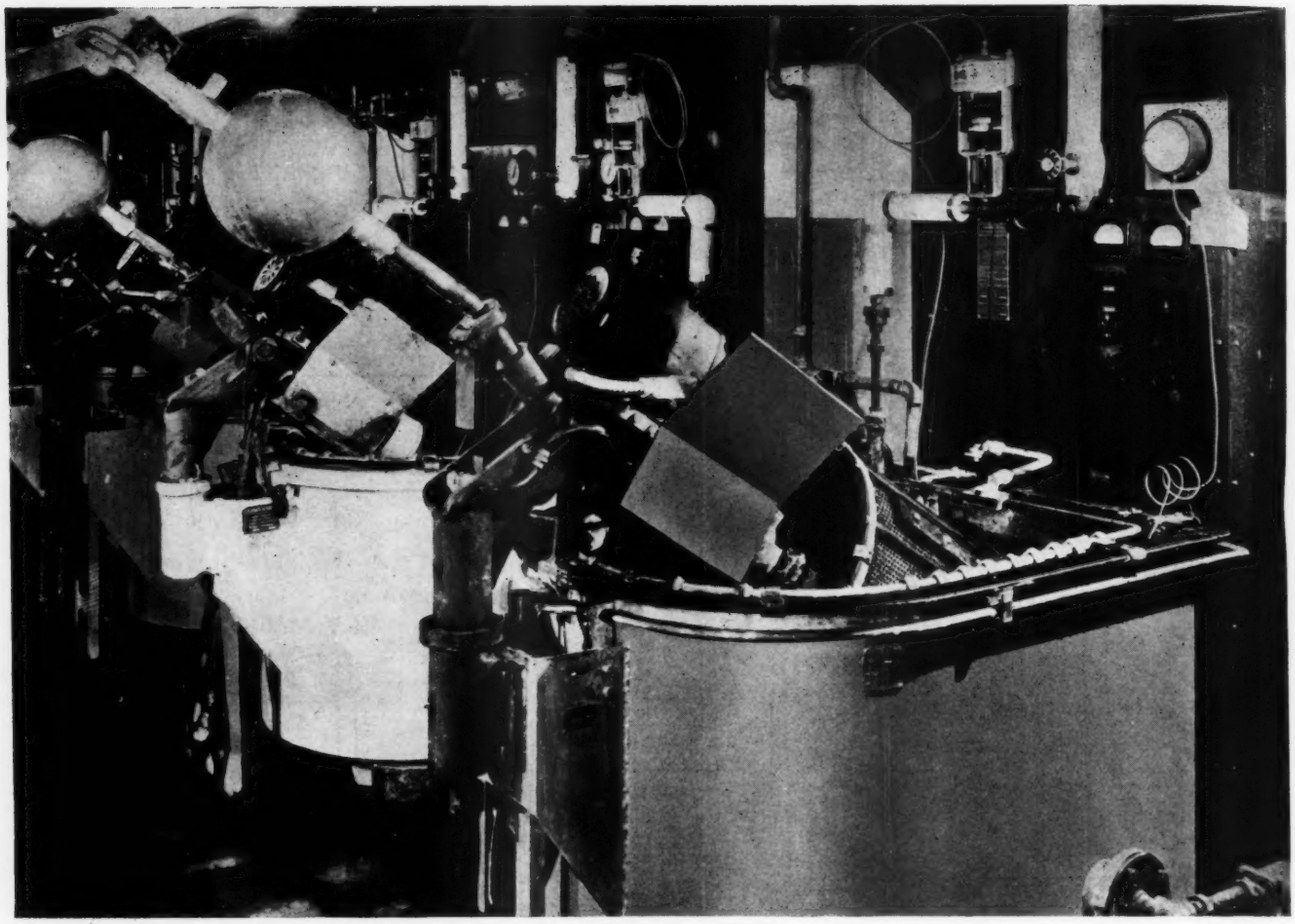


FIG. 10 - SMALL GASOLINE ENGINE



Hi-speed copper plating barrels

MATERIALS AND COATINGS

Precautions in Selection to Avoid Service Troubles

A. W. ROGERS
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DESPITE the emphasis placed upon "machine design calculations" in college textbooks and engineering courses, stress calculations usually play only a minor part in most design problems in industry. Admittedly, in load-carrying members wherein weight must be held to a minimum stress and deflection calculations are highly important. But in many cases, it is permissible to increase weight and dimensions to compensate for lower physical properties of the proposed material. If only obvious physical properties are subjected to close analysis, trouble may ensue because stress and deflection are frequently overshadowed by other considerations such as production problems, effects produced by contact with or the proximity of other materials, surface and intergranular corrosion and similar factors.

The present necessity of substituting another material for one that has become scarce or unobtainable, and the desire to speed production by the use of new methods and processes compels exhaustive studies by the engineering department to avoid misapplications and to provide against unfavorable conditions. Unfortunately there are no rules or formulas for the solution of such problems. A new manufacturing process may disintegrate a material even though the effect is not immediately visible; a new material may cause corrosion at its surfaces of contact with other certain materials; a material may be reasonably resistant to corrosion when subjected to ordinary accelerated tests but will corrode rapidly if the material is under stress; a certain

synthetic material may be perfectly satisfactory in itself but fumes emanating from it may corrode other materials in the machine or device. The following items are based on the experiences of the engineers of the meter division of the Westinghouse Electric & Manufacturing Company in design of meters and instruments. These experiences are merely indicative of the vast range and complexity of the problems encountered in the selection of materials and the precautions that must be taken.

Furnace Brazing

Controlled atmosphere brazing is being used more and more for assembling intricate shapes. When brazing steel parts a reducing atmosphere with hydrogen as the reducing agent is highly desirable in order that the oxide coatings on the steel will be reduced. But ordinary copper contains oxygen which immediately combines with the hydrogen in the brazing atmosphere to form water. Under the high temperature in the brazing furnace, between 1,300 and 1,800 deg. F., the water formed changes immediately to steam at extremely high pressure, a pressure sufficiently high to cause minute explosions which literally burst the copper into granules. Of course this condition also exists when brazing copper pieces. Any assembly made of ordinary copper which is to be brazed in a hydrogen atmosphere is likely to crack or break at extremely low stresses. For this reason it is important that oxygen-free copper be used for copper parts that are to be assembled by brazing.

Which Brass to Use

Brass is frequently used for parts exposed to the weather. Cover rims and other assemblies for meters to be used outdoors are examples. However, it is highly important that the right kind of a brass be used in such applications. Ordinary yellow brass is subject to season cracking or intergranular corrosion. In metallurgical terms, any brass which contains both alpha and beta phases of copper and zinc is subject to intergranular corrosion. That is, the zinc-rich or beta phase segregation forms corrosion cells which eventually cause disintegration of these parts. This intergranular corrosion is more pronounced when the material is under stress. For this reason it is highly important to use a low brass or bronze when the part or assembly is to be exposed to the weather. In general, the meter division of the Westinghouse company has adopted the practice of using an outdoor grade of brass with a typical analysis of 80 percent copper and 20 percent zinc for sheet and strip. For applications where good machining properties are highly desirable, a typical analysis of 85 percent copper, 13.25 percent zinc and 1.75 percent lead is used. For hardware where cold heading properties are needed, a typical analysis is 90 percent copper and 10 percent zinc.

Rust-Protective Coatings

Whenever a new material or process becomes available and holds forth great promise for accomplishing certain desired results, it is invariably misapplied before its limitations are known. For example, cadmium plating for the protection of steel and iron parts was considered to have many points of superiority over zinc. In spite of the fact that it costs more than zinc, its applications became very extensive, even where zinc coatings were previously satisfactory. But cadmium is highly sensitive to organic acids produced by the aging or oxidation of most of the oils and resins commonly used in insulating varnishes for coil impregnation, tubing coating, and varnished tapes. These organic acids act more or less as catalysts in promoting the hydrolysis or oxidation of cadmium plating. It has been found even in indoor exposures where atmospheric conditions are relatively favorable that quantities of white or gray corrosion products are formed on the cadmium surface. Where cadmium plating is necessary this problem can be solved by the proper choice of insulating materials. If the problem cannot be solved in this manner the only solution is to eliminate cadmium plating and to use zinc or some other material in its place.

Phenolic Resins

Molded phenolic resins in combination with various fillers such as wood flour, mica clay, cotton flock, and others are used almost universally in the electrical industry. Of course the specific resin selected must have the required strength, impact resistance and insulation properties. In addition, it is highly important that it have low shrinkage characteristics and a low volatile content. By experience in instrument applications, we have found it necessary to use a molded composition with extremely low shrinkage characteristics and extremely low volatile content. In one of our materials we actually specified the volatile content and the shrinkage allowable on exposure to 100 hr. at 110 to 120 deg. C. Low volatile content can be obtained only by properly curing the phenolic material. Fumes given off from improperly cured phenolic resin parts are in some instances highly corrosive and are likely to discolor white organic finishes. In fact, a common test in our engineering department for the stability of white lacquer is to expose finished pieces to the fumes of phenolic molding powder.

Thermoplastic Resins

Many of the new resins available have had a pronounced effect on design in the electrical industry. Thermo-plastic sheeting is used extensively for insulating purposes, and thermo-plastic resins are used in formulations of insulating varnishes, treated cloth, insulating lacquers, extruded insulating tubing, and lacquer-coated tubing. In our experiences, there are three factors which determine the uses of these materials.

(1) Aging characteristics must be such that when exposed to temperatures common for class *A* insulation, the material has a reasonable life measured in terms of brittleness, strength and appearance.

(2) Whenever a plasticizer is used in forming or compounding resin, its application should be considered carefully, because prolonged exposure to heat and moisture will in most cases remove or drive off the plasticizers. This will have several bad effects, especially in closed apparatus. Volatile materials driven off from the plastics will condense on the cool surfaces of the device or instrument, for example, the surfaces of the meter covers and instrument bezels. The volatilization of the plasticizer also will cause shrinkage of the plastic parts. This is usually highly destructive, particularly when the resin is being used in a structural member.

(3) Aging or breakdown products of the resins in some cases may be highly active acids. For this reason, we favor the use of resins which do not have acid radicals.

Organic Finishing

Preparation of metal surfaces prior to either lacquering or japanning is as important as the protective coating itself. For example, the etching of aluminum die castings or fabricated sheet before finishing serves two purposes; it not only thoroughly cleans the surface, removing all grease, oils and foreign material, but it also produces a rough surface which will give a large bonding area for the organic finish to be applied later. Shot blasting or sand blasting is also a common method for roughing and cleaning metal surfaces before finishing. Bonderizing or Parkerizing of either steel or zinc also serves as a bond for organic

finishes. With reference to Bonderizing, it might be said that it will double the effectiveness of ordinary lacquers.

Electroplating

Some months ago we were faced with the problem of inclosing our watthour meter magnets with a good electrical conductor for surge protection. This conductor served to damp current peaks that occurred during lightning surges, thereby preventing demagnetization. After convassing several possibilities, it was decided that high-speed copper plating might produce a satisfactory product. After months of development, a process was developed for plating twenty thousandths of an inch of copper on a "C"-shaped magnet which has a narrow air gap. Conductivities approach that of wrought conductors. The smooth surface, finished with an aluminum lacquer, has a pleasing appearance.

Plating is done in a tumbling barrel. Many innovations in this method of plating were necessary in order to meet production requirements of several thousand units a day weighing about one-third pound each. In addition to the details of solution development, the correct proportion of slugs to a magnet load had to be determined and one pole tip of each magnet had to be masked. Masking was done successfully by placing a close-fitting short section of tubing over the pole tip, using a special fixture.

As a tubing material Neoprene proved very satisfactory, but it has been necessary to discontinue its use and to substitute rubber tubing in this national emergency. The physical characteristics of the tubing have to be such that it can be stretched over the pole tip and at the same time stand up under the continual pounding of the sharp edges of the magnets and slugs.

Galvanizing

In applications where it is desirable to prevent steel from rusting, the use of zinc has been long established, particularly for outdoor roofing, hardware, tanks, cans and such. In practically all cases the zinc is applied by hot dipping methods; in recent years electro-deposition of zinc has become general. Several steel companies are now producing sheet which has been electro-galvanized.

It has always been recognized by authorities that under certain conditions, zinc produces voluminous corrosion products. The protection of zinc on iron or steel is the result of preferential corrosion, hence a much more rapid rate of corrosion can be expected when the zinc plate is porous. In normal galvanizing applications, these voluminous corrosion products are of no concern because they are continually being washed away or otherwise removed from the surface of the metal. But in inclosed apparatus the corrosion products remain on the metal surface. This is a serious problem in delicate apparatus particularly since small amounts of any foreign material in jewel bearings will be fatal in most cases. And even though the operation of the apparatus may not be impaired, the appearance of this so-called "white rust" is disturbing to a customer. A moist, humid atmosphere accompanied by relatively high temperatures, 100 to 150 deg. F, is a condition conducive to such corrosion. Outdoor weather may aggravate this further because of cycles of condensation. Thus conditions of actual immersion and 100 percent humidity may exist inside a meter case in daily cycles. Proper ventilation and breathing holes help greatly in alleviating the cause of this trouble.

It is evident from the above that if the surface is properly passivated or made inert, it is possible to prevent the formation of white powder. Certain available commercial processes which do this serve as passivators. The Cronak process and the Bonderizing process are two examples of such processes in use at the present time.

In most applications the Cronak process—essentially a chromic acid treatment—is effective in preventing the formation of white powder or corrosion. It has not been used to any great extent as a preparatory finish before painting, lacquering or japanning for protection of electro-galvanizing. In our experiments, under some conditions of heat exposure the protection of the Cronak finish was destroyed. As long as there is sufficient water present, the finish is not destroyed. This has led to the supposition that if the water of crystallization is removed from the finish it is no longer effective. The temperature ranges used in the tests were within those limits common in the operation of meters and instruments.

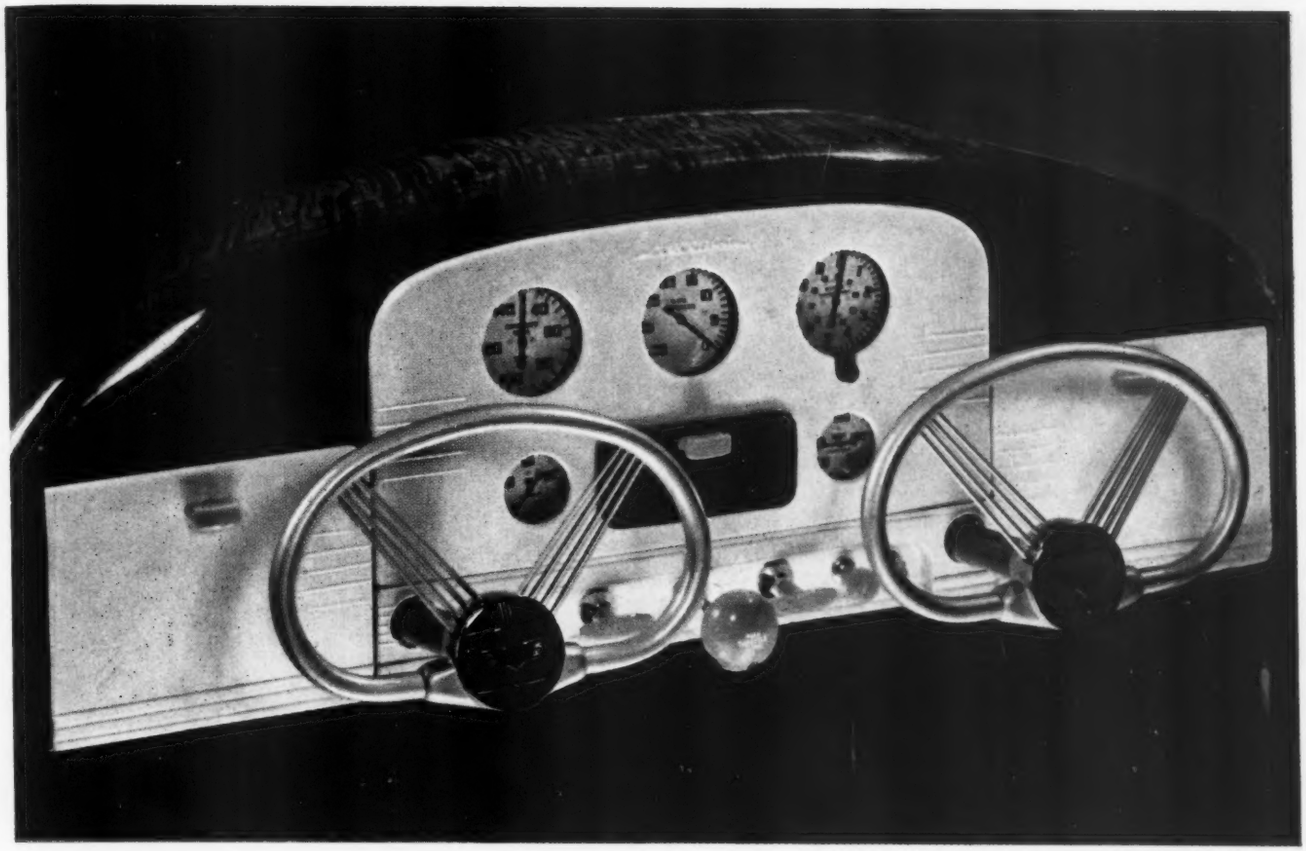
The formation of a phosphate coating on the surface of zinc plating, Bonderizing, has been found effective in further increasing the protection of zinc and in preventing the formation of voluminous corrosion products. In addition, the crystal structure and absorption characteristics of this surface make it an excellent bonding medium for any organic finish. It is not at all affected by temperatures normally found in metering apparatus. Under some test conditions, the corrosion protection is found to have been increased as much as ten fold. For instance, in a steam box test running at 140 deg. F. a zinc coat 0.0005 in. thick will last approximately 72 hr. before rusting occurs on the base metal. This process should play an important part in the present national emergency as it may make possible the substitution of steel castings or drawn parts for zinc or aluminum parts, particularly when these two metals are used primarily for corrosion resistance.

Electrolysis

In addition to the general corrosion caused by normal breakdown of a metallic surface, occasional troubles may occur from electrolysis caused by metallic contact of metals which are far apart in the electro-chemical series. In outdoor apparatus this may be particularly troublesome if condensation is likely to occur or if water leaking into the case causes periodic immersion of metallic couples. For instance, cadmium-plated steel screws in contact with tin-plated brass cause rapid corrosion of the cadmium under conditions of total or partial immersion. By using a dual plate of cadmium and tin with tin as the outer coating the electrolysis can be greatly reduced. In the same manner, by properly choosing a plating metal it is possible to eliminate seizing of screws caused by electrolytic corrosion of two dissimilar metals. For instance, steel screws which are to be used in aluminum can be cadmium-plated and seizing practically eliminated.

From the above case studies, it is apparent that before choosing a definite material or process, the design engineer should make tests based on actual service conditions so that the effect of operating factors on strength, corrosion resistance and part life may be determined in advance. Thus many troubles can be anticipated and worked out before actual production starts. This is particularly important today when many changes and substitutions must be made.

In the Westinghouse plant our exposure tests are made on the roof which is typical of an industrial atmosphere since the air contains a large percentage of sulphur fumes. These exposure tests are always supplemented by salt spray, steam box, sulphur dioxide atmosphere, ultra-violet Fadeometer, humidor and oven tests. In practically all cases accelerated tests are carefully examined for their value in interpreting the results in terms of outdoor exposure. Only by experience and parallel tests in actual outdoor exposure can this be done with any degree of dependability. The value of any accelerated test depends on relative conditions where a known material or product is used for a control.



Three molded Lustron parts are mounted on sheet steel panel with vibration resistant Speednuts in this Aeronca instrument board, molded by Atlantic Plastic and Die Cast Company and by Thermoplastic Division of Standard Products Company

POLYSTYRENE PLASTIC

Physical Properties and Typical Applications

SHORTAGES in certain metals, which are required in the defense program, have focused attention on plastics as alternate or replacement materials. Thus many engineers redesigning aluminum parts such as interior doors on refrigerators, or die-cast zinc or brass housings have considered the possible use of plastics. Service conditions will dictate the type of plastic material and the method of molding, but the wide range of available materials makes any choice at best a difficult job.

In choosing a material for injection molding, tendency to cold flow, dimensional instability, loss of strength at low or high temperatures, water absorption characteristics and the like must be balanced against factors such as ease of production, inherent finish, range of color and sales appeal. These materials may be cellulose acetate, cellulose acetate-butyrate or polystyrene. Also, each of these plastics may have one or two desirable properties which may affect choice profoundly—for instance, where high dielectric strengths are required polystyrene is almost always used.

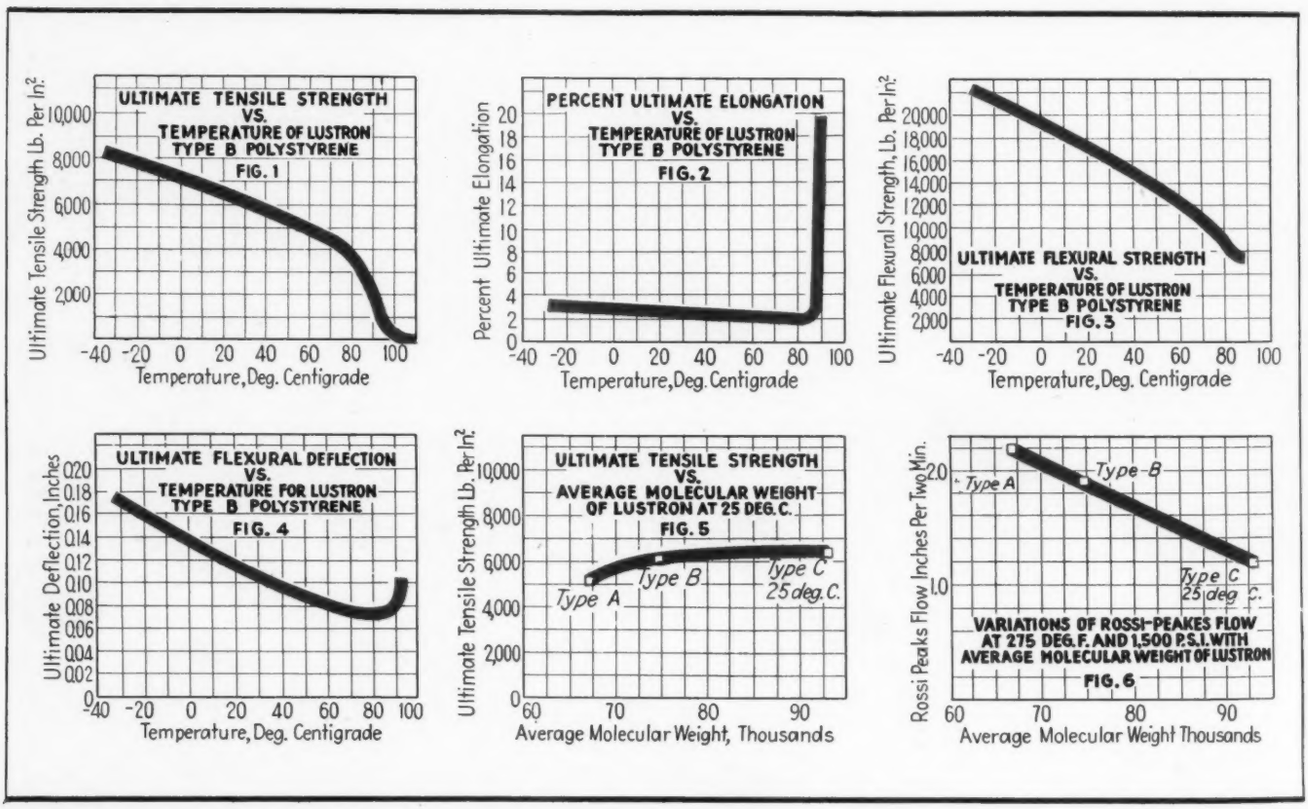
Dimensional changes on aging occur to a certain extent with all plastics, but to a lesser degree when the materials are unplasticized and have little or no water absorption. Cellulose acetate has plasticizers added to improve flow in the molding operation: after molding, the plasticizers leave the part and dimensional changes may occur. Polystyrene, on the other hand, is plasticized by the action of heat alone; no extra plasticizers are used. As a result, dimensional changes on aging are slight. Mold shrinkage of polystyrene is of the order of 0.002 to 0.008 in. per inch.

The other factor that affects dimensional stability is the amount of water absorption. High humidity conditions affect molding properties and may cause swelling of parts in service. Based on 24-hr. tests, polystyrene absorbs only a small percentage of water—0.00 to 0.03 percent. As an example, polystyrene is used for the five molded parts on a therapeutic device in contact with hot water. These parts are friction fits and

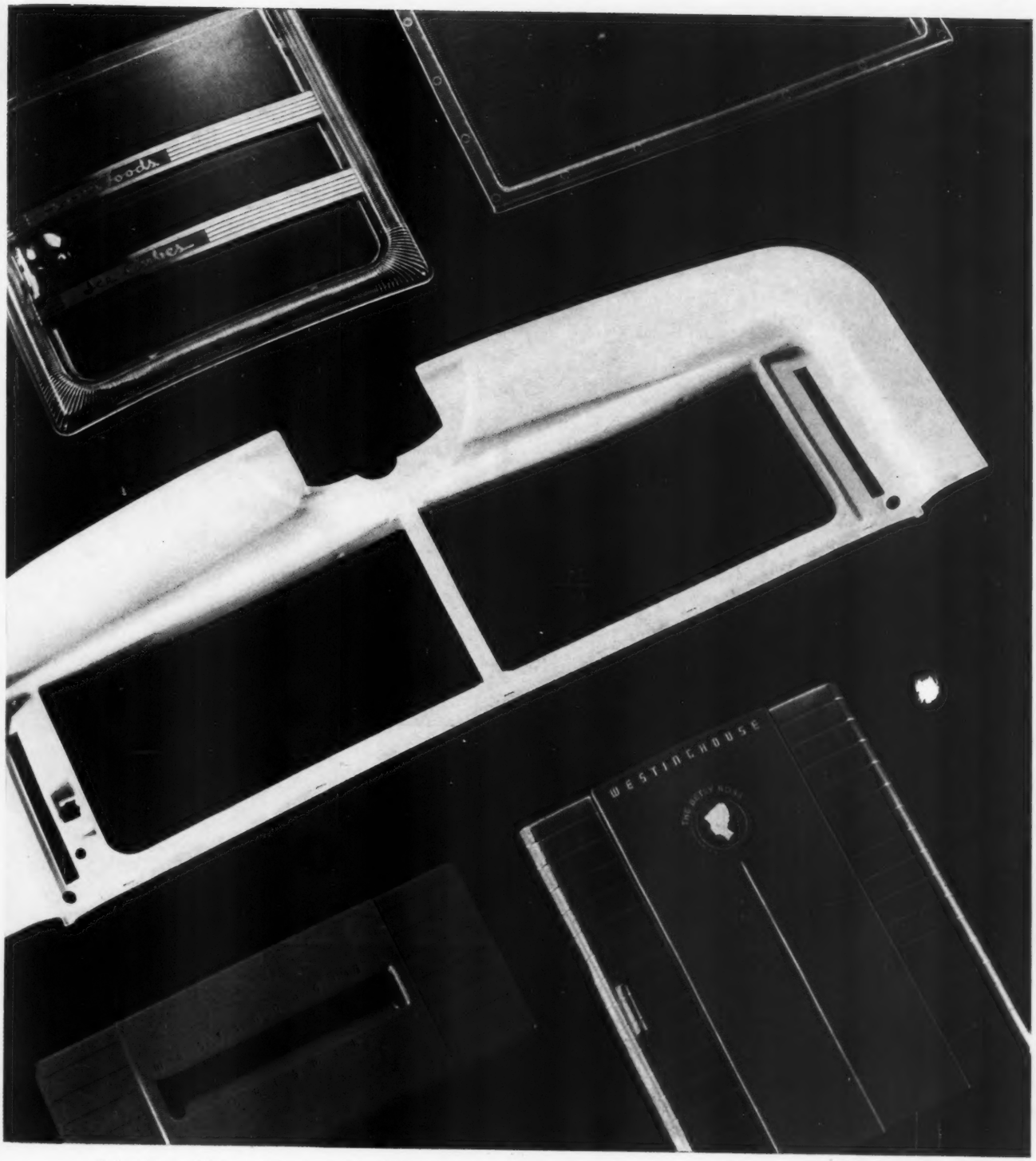
Properties of Polystyrene

Compression molding temperature, deg. F	275–350
Compression molding pressure, lb. per sq. in	1,000–5,000
Injection molding temperature, deg. F	300–500
Injection molding pressure, lb. per sq. in	10,000 and up
Compression ratio	2.0–2.3
Mold shrinkage, in. per in.	Compression 0.002–0.005
Mold shrinkage, in. per in.	Injection 0.002–0.008
Specific gravity	1.051–1.070
Specific volume, cu. in. per lb.	26.3–25.9
Refractive index	1.59
Tensile strength, lb. per sq. in.	5,000–9,000
Elongation, percent	2–5
Modulus of elasticity, in tension lb. per sq. in.	1.7–2.6 x 10^5
Compressive strength, lb. per sq. in.	11,500–13,500
Flexural strength, lb. per sq. in.	14,000–19,000
Impact strength, ft. lb. per in. of notch ½ x ½ in. notched bar, Izod Test	0.35–0.50
Brinell hardness (2.5 mm. ball, 25 kg. load)	20–30
Rockwell hardness	M87–M90
Light transmission	88–90 percent
Thermal conductivity 10^{-4} Cal. per sec. per sq. cm. per 1 deg. C. per cm	1.9
Specific heat, cal. per deg. C. per gram	0.32
Thermal expansion, per degree centigrade	6–8 x 10^5
Resistance to heat, deg. F. (continuous)	———
Softening point, deg. F	190–230
Distortion under heat, deg. F. (A. S. T. M.)	170–180
Tendency to cold flow	Slight
Volume resistivity, ohm-cms. (50 per cent R. H. and 25 deg. C.)	10^{17}–10^{19}
Dielectric strength, short time volts per mil ⅛ in. thickness	500–700
Dielectric constant, 60 cycles	2.5–2.6
Dielectric constant, 10^3 cycles	2.5–2.6
Dielectric constant, 10^6 cycles	2.5–2.6
Power factor, 60 cycles	0.0001–0.0002
Power factor, 10^3 cycles	0.0001–0.0002
Power factor, 10^6 cycles	0.0001–0.0001
Water absorption, immersion 24 hr	0.00
Burning rate	Moderate
Effect of age	Slight
Effect of sunlight	Yellows slightly
Effect of weak acids and strong acids	None
Effect of weak alkalis and strong alkalis	None
Effect of organic solvents	Soluble in aromatic and chlorinated hydrocarbons
Machining qualities	Fair
Color possibilities	Unlimited
Effect on metal inserts	None

Optical Properties — Light transmission is 88–90 percent, in the visible region (4,000 deg. A–7,000 deg. A). Because of high refractive index (1.59), the theoretical transmission is only 92 percent. An interesting property is internal reflection. Parts carry light which glows only at edges or at points where the surface is roughened.


ULTIMATE TENSILE STRENGTH VS. TEMPERATURE OF LUSTRON TYPE B POLYSTYRENE FIG. 1
Ultimate Tensile Strength Lb. Per In.²
Temperature, Deg. Centigrade
PERCENT ULTIMATE ELONGATION VS. TEMPERATURE OF LUSTRON TYPE B POLYSTYRENE FIG. 2
Percent Ultimate Elongation
Temperature, Deg. Centigrade
ULTIMATE FLEXURAL STRENGTH VS. TEMPERATURE OF LUSTRON TYPE B POLYSTYRENE FIG. 3
Ultimate Flexural Strength, Lb. Per In.²
Temperature, Deg. Centigrade
ULTIMATE FLEXURAL DEFLECTION VS. TEMPERATURE FOR LUSTRON TYPE B POLYSTYRENE FIG. 4
Ultimate Deflection, Inches
Temperature, Deg. Centigrade
ULTIMATE TENSILE STRENGTH VS. AVERAGE MOLECULAR WEIGHT OF LUSTRON AT 25 DEG. C. FIG. 5
Type A
Type B
Type C 25 deg. C.
Ultimate Tensile Strength Lb. Per In.²
Average Molecular Weight, Thousands
Type A
Type B
Type C 25 deg. C.
VARIATIONS OF ROSSI-PEAKES FLOW AT 275 DEG. F. AND 1,500 P.S.I. WITH AVERAGE MOLECULAR WEIGHT OF LUSTRON FIG. 6
Rossi Peaks Flow Inches Per Two Min.
Average Molecular Weight Thousands

Figs. 1. and 2.—Tensile strength and elongation determined simultaneously over a range of temperatures with injection-molded dumbbell-shaped test specimens of ¼ in. x ¼ in. cross-section on a screw type tensile strength testing machine. Figs. 3 and 4—Flexural strength and deflection at various temperatures as determined by tests on a 2 x ¼ x ¼ in. test specimen. Fig. 5—Strength increase with molecular weight. Fig. 6—Rossi-Peakes flow values showing flow decrease with increase in molecular weight



Injection moldings of Lustron for 1941 refrigerators. Center molding is one of the largest ever produced

have not loosened or warped in service.

The upper limit of temperature for polystyrene parts is about 170 deg. F., as compared with an upper limit of 150 deg. F. for cellulose acetate parts. In this connection, this relatively low upper limit of temperature to a certain extent limits industrial applications of injection molded parts.

One interesting characteristic of polystyrene is the fact that strength of the material increases at low temperatures. At 140 deg. F. polystyrene has a tensile strength of 5,000 lb. per sq. in.; at −4 deg. F. tensile strength is 8,000 lb. per sq. in. This behavior, coupled with the material's low moisture absorption and good dimensional stability, has led to its widespread adoption for refrigerator interior parts such as insulating frames, freezing unit doors, drip traps and food bins. These parts are exposed to food acids, cleansing agents, variations in humidity and low temperatures.

High electrical properties are characteristic of certain compression molding materials, notably urea formaldehyde and mica-filled phenolics. Of the injection molded materials, polystyrene alone has high electrical strength. Thus it is widely used for coil forms, stand-off insulators, sockets, high-frequency lead-ins and co-axial cable spacers in

Small injection moldings of Lustron for small storage batteries, electrical parts and consumer products

Polystyrene, known to chemists for over a hundred years, is made by a series of reactions from two organic compounds, benzene and ethylene. These are combined to form ethyl benzene and then subjected to a cracking operation under high heat and pressure to remove hydrogen from the molecule. The product of this reaction is styrene monomer, a clear water-white liquid. Polystyrene is derived from this material by polymerization, a reaction which links the individual molecules of styrene in long chains, converting the liquid to a hard tough, transparent resin. Colored molding materials are made by working dyestuffs or pigments into the clear transparent material on heated rolls which knead the plastic and disperse the color. After rolling, the material is removed in rough, uneven sheets which are allowed to cool and harden, then ground to a molding powder.

which the polystyrene is molded in the form of beads strung on a central connecting wire, the beads providing flexibility and also centering the cable from the side walls. As an example of electrical insulation properties, if the loss factor (power absorbed by insulation at 60 cycles), of polystyrene is rated as one, that of low-loss phenolic is 458, urea 740 and general-purpose phenolic 10,000. Loss factor becomes more important as frequency increases. For short-wave equipment, specifications require that when the insulating material is placed in a 30-million-cycle field, the temperature of the part shall not rise more than 10 deg. F. above ambient. Of all the plastic materials, only polystyrene can meet this requirement. So far as resistivity is concerned, the ratio of polystyrene to phenolic low-loss is 1,000 to 1, that of polystyrene to general purpose phenolic 10,000 to 9. See P.E. Dec. 1938, page 464, for further data comparing electrical properties of the various plastics.

In so far as weight per unit volume is concerned, this material is 17 to 25 percent lighter than other thermoplastics. Thus more parts per pound can be molded, and on a poundage basis, the material may be in some cases the lowest priced of all injection molded plastics.

Whenever possible, it is good practice to design polystyrene parts so that only a minimum of machining will be required. Machining characteristics are only fair, as the material tends to gum up under the tool. If tapped holes are required, it may be best design to incorporate inserts in the molded part. However, when machining must be done, cold water is the best coolant.

Kodachromes and research data for this article were supplied through the courtesy of the Plastics Division, Monsanto Chemical Company.

CRANK MECHANISM MOTIONS

New Methods for Their Exact Determination — III

Dr. WERNER F. VOGEL
Wayne University, Engineering College

IN THE FIRST of four articles (June P.E.) the approximate and exact forms of the principal equations of the crank-connecting rod mechanism were discussed and illustrated. Part II (July P.E.) presented new exact methods for computing crank-connecting rod-piston relationships which are simpler than approximate equations in common use. New graphical methods were introduced.

In this article the detailed characteristics of crank-connecting rod motions are described and illustrated graphically, particularly to show the effect of variation of the connecting rod ratio and the error of some special approximate equations. An exact solution for maximum piston velocity, simple enough for practical computation, is presented for the first time.

Since several references are made to tables and illustrations in Parts I and II, it will be convenient to have the June and July P.E. at hand while following Part III.

Maximum of Piston Velocity

The determination of maximum piston velocity must be preceded by the design of the corresponding mechanism's position. Actually, the maximum value of velocity $c_{max.}$ is often less important than the abscissa x^* of the vertex S^* of the velocity curve. Since x^* locates at the same time the zero point Q^* of the acceleration curve, as in Fig. 1, the knowledge of x^* permits drawing the simplified and more dependable acceleration graph shown in Fig. 20.

There have been continued efforts (Ref. 3, Part I) to find exact methods of computing this maximum, but in none of the earlier publications could general equations be expressed simply enough to be evaluated in practical numerical computations. Therefore, the following computing method is the first simple and exact solution for maximum velocity.

Exact Computing Method of $c_{max.}$:

Maximum velocity occurs when

$$a = \frac{dc}{dt} = 0$$

When Equation (17) equals zero:

$$a = \omega^2(\xi - R_2 \sin^3 \psi) \qquad (17)$$

Equation (17) can be converted to:

$$\cos\frac{\psi^*}{2} - \cos^3\frac{\psi^*}{2} = \sqrt{\frac{1-\lambda^2}{8}} \qquad (24)$$

A simple solution of this cubic equation is possible by introducing an auxiliary angle ϕ, as Equations (25) and (26) of Table VIII show.

After having determined ψ^* by Equation (24), all other required computing values can be easily found by putting the numerical values of ψ^* into the corresponding general equations of Table VI. Even simpler is the use of the new special Equations (27) to (31) of Table VIII. The following example illustrates the above.

PROBLEM 5:

Using the crank mechanism of Problem 1 ($r = 0.21$ ft., $l = 0.7$ ft., $\omega = 314.16$ rad./sec., $f = 0.66776$ ft.) the piston's position and velocity are to be computed for a maximum of the latter.

Ratio: $\lambda = \frac{r}{l} = \frac{0.21}{0.7} = 0.3$

(*Continued on next page*)

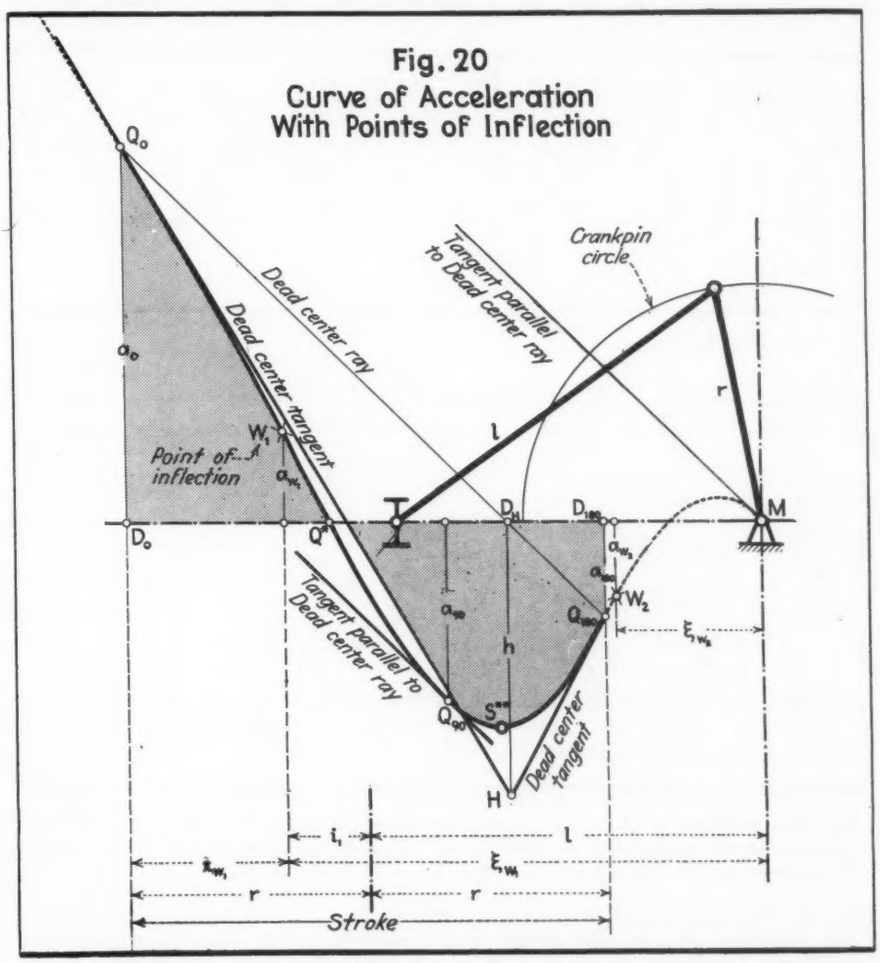
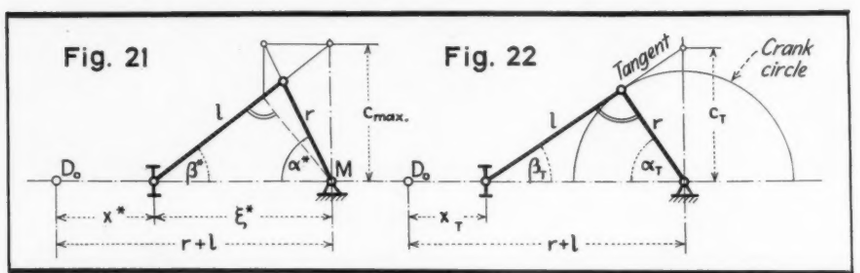


Fig. 20—Acceleration curve shows the real point of inflection W_1 while W_2 is located on the dotted part of the curve outside the stroke. Occurrence of these points depends on the ratio $\lambda = r/l$. Location of Q_0, Q_{90}, and Q_{180} and tangents at these points is the same as shown in Fig. 4. Location of W_1 can be found without using the crank center M by making $i = r\ (1.51\ \lambda_t - 1)/\lambda$

Table VIII—Exact Equations for the Maximum Velocity

Only the sign indicated before the root should be employed. See Fig. 21 for mechanism's special position, designated by a star at the symbols. For significance of ψ see Fig. 11. ϕ is an auxiliary angle (not shown in figure) only introduced for simplification of this special computation.

Denotation			Equation	No.
Auxiliary Angle.....		ϕ	$\cos\phi = -\frac{3}{4}\sqrt{1.5\,(1-\lambda^2)}$	(25)
Angle of Fixed Point's Ray..		ψ^*	$\cos\frac{\psi^*}{2} = +\sqrt{\frac{4}{3}}\,.\,\cos\frac{\phi}{3}$	(26)
Position of	Piston.....	ξ^*	$\xi^* = f\,.\,\text{cotan}\,\frac{\psi^*}{2}$	(27)
	Connecting Rod.	β^*	$\cos\beta^* = \sqrt{2}\,.\,\sin\frac{\psi^*}{2} = 1.4142\sin\frac{\psi^*}{2}$	(28)
	Crank.....	α^*	$\sin\alpha^* = \frac{\sin\beta^*}{\lambda} = \frac{+\sqrt{\cos\psi^*}}{\lambda}$	(29)
Piston's Maximum Velocity.		$c_{max.}$	$c_{max.} = \xi^*\,\omega\,.\,\tan\beta^*$	(30)
			$= +l\,.\,\omega\,(1+\cos\psi^*)\,\sqrt{\cos\psi^*}$	(31)



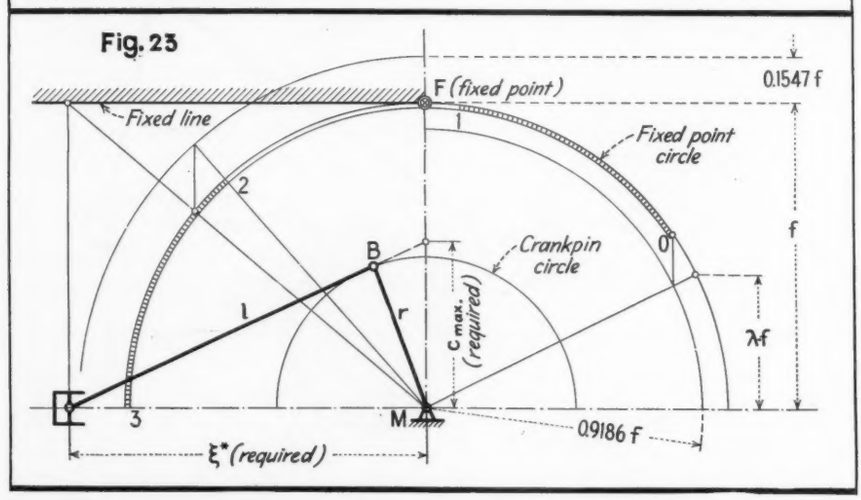


Fig. 21—Graphical analysis for maximum piston velocity $c_{max.}$ Maximum velocity occurs when the vector MN of acceleration in Fig. 1 shrinks to zero ($a = o$). Exact computation of $c_{max.}$ is given in Table VIII

Fig. 22—The error in the common assumption that $c_{max.}$ occurs in the tangential position is apparent by comparing the above diagram with Fig. 21. This evident difference does not mean that c_T cannot be used as a fair substitute for $c_{max.}$ For error of this approximation see error curves, Figs. 28-30

Fig. 23—To determine the position for maximum piston velocity, find the point 0 on the fixed-point circle as shown and trisect the arc 0 — 3. Start at point 2 to locate the positions of piston and crank

Auxiliary angle: $\cos\phi = -\frac{3}{4}\sqrt{1.5(1-0.3^2)}$

$= -0.87625$; $\phi = 151°\ 11'\ 35''$

Angle of Ray to Fixed Point:

$\cos\frac{\psi^*}{2} = +\sqrt{\frac{4}{3}}\,.\,\cos\frac{\phi}{3} =$

$1.1547\ .\ \cos 50°\ 23'\ 52'' = 0.73607$

$\frac{\psi^*}{2} = 42°\ 36'\ 8''$; $\quad\text{cotan}\,\frac{\psi^*}{2} = 1.0874$

$\psi^* = 85°\ 12'\ 16''$; $\quad\cos\psi^* = 0.08360$

Position of Piston:

$\xi^* = f\,.\,\text{cotan}\,\frac{\psi^*}{2} = 0.66776 \times 1.0874$

$= 0.7261$ ft.

$x^* = r + l - \xi^* = 0.21 + 0.7 - 0.7261$

$= 0.1839$ ft.

Maximum Velocity of Piston

$c_{max.} = l\,.\,\omega\,.\,(1+\cos\psi^*)\,.\,\sqrt{\cos\psi^*}$

$= 0.7 \times 314.16 \times 1.08360 \times \sqrt{0.08360}$

$= 68.90$ ft./sec.

Graphical Determination of $c_{max.}$:

A graph for determining all needed values of $c_{max.}$ based on the new exact equations, is shown in Fig. 23. The approximate construction, Fig. 22, will be discussed in the next section. Still simpler is the nomograph, Fig. 24, which provides all needed values α^*, x^*, and $c_{max.}$ with sufficient accuracy.

The curves, Figs. 25 to 27, show in a wider range the influence of the ratio λ on the coordinated angles, piston displacement, and velocity.

Approximate Formulas for $c_{max.}$:

The previous lack of an easily usable exact formula has caused the development of approximate formulas. Since some of them are in common use and yield results quicker than the exact equations of Table VIII, their worth and suitability are tested here by means of error curves.

1. Formulas of the T-Position:

In various publications the "tangential position" (T-position) of the connecting rod to the crank circle, as shown in Fig. 22, is considered to be the position of maximum piston velocity. The error in this assumption can be seen by comparison with Fig. 21.

Therefore, when replacing equations of the $c_{max.}$-position by those of the T-position, they must be characterized as approximate equations and written:

$$\text{cotan}\,\alpha^* \sim \text{cotan}\,\alpha_T = \tan\beta_T = \lambda \quad \text{(A7)}$$

$$x^* \sim x_T = r + l - \sqrt{r^2 + l^2} \quad \text{(A8)}$$

$$c_{max.} \sim c_T = r\,.\,\omega\,.\,\sqrt{1+\lambda^2} \quad \text{(A9)}$$

2. Formulas Derived from the Approximate Principal Equations

If in Equation (A4):

$$a = r\omega^2\,(\cos\alpha + \lambda\cos 2\alpha) = 0,$$

then: $$\cos\alpha^* = \frac{\sqrt{1+8\lambda^2}-1}{4\lambda} \quad \text{(A10)}$$

This equation may be used with the

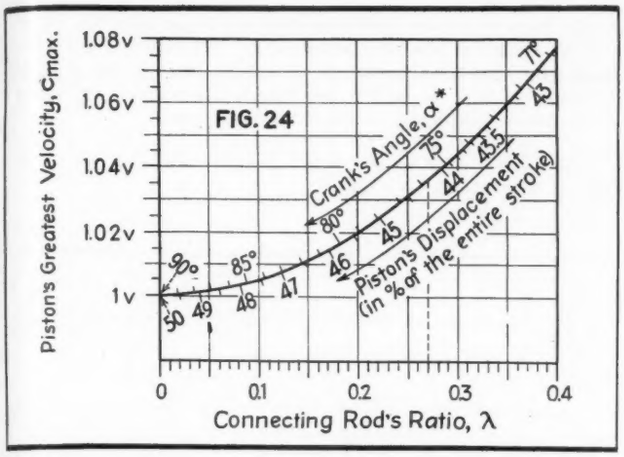
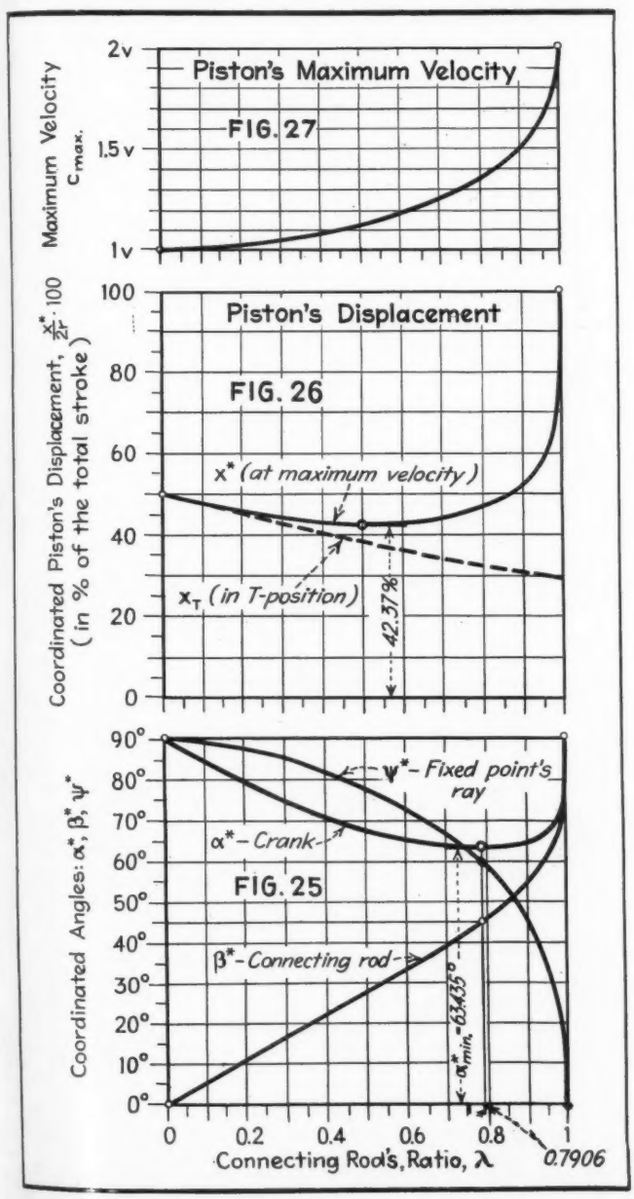


Fig. 24—Maximum piston velocity and the coordinated position of the mechanism may be determined by this nomograph. For example when λ = 0.27, find $c_{max} = 1{,}0355v$ as the ordinate of the curve. The crank angle $\alpha^* = 75.7$ deg. and piston displacement of 44.2 percent are indicated by graduations on the curve



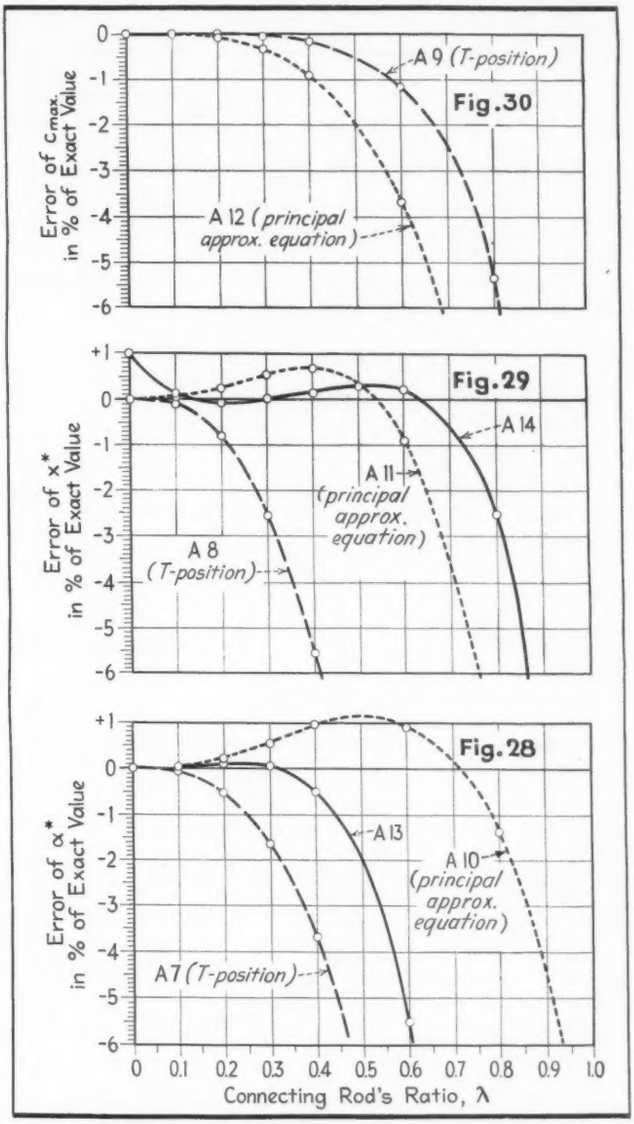


Fig. 25—Effect of connecting rod ratio λ at maximum piston velocity on the crank and connecting rod angles and on ψ^* is shown. Minimum α^* (63.435 deg.) occurs when $\beta^* = 45$ deg. and $\psi^* = 60$ deg.

Fig. 26—Effect of λ at $c_{max.}$ on coordinated piston displacement is shown. Comparison is made to the displacement of the T-position, whose use as a substitute was described in Fig. 22

Fig. 27—Maximum values of piston velocity $c_{max.}$ as affected by λ. The piston velocity is shown as multiple of the crankpin's velocity $v = r\omega$

Fig. 28—Errors of crank displacement α^* resulting from use of approximate Equations (A7), (A10) and (A13). In the usual range of λ (λ = 0 to 0.35) the new Equation (A13) shows the smallest errors

Fig. 29—Errors of piston displacement x^* when using Equations (A8), (A11) and (A14). The new Equation (A14) gives the closest approximation

Fig. 30—Errors of maximum velocity $c_{max.}$ when using Equations (A9) and (A12). In the most common range, λ = 0 to 0.35, the simple Equation (A9) of the T-position gives a good approximation

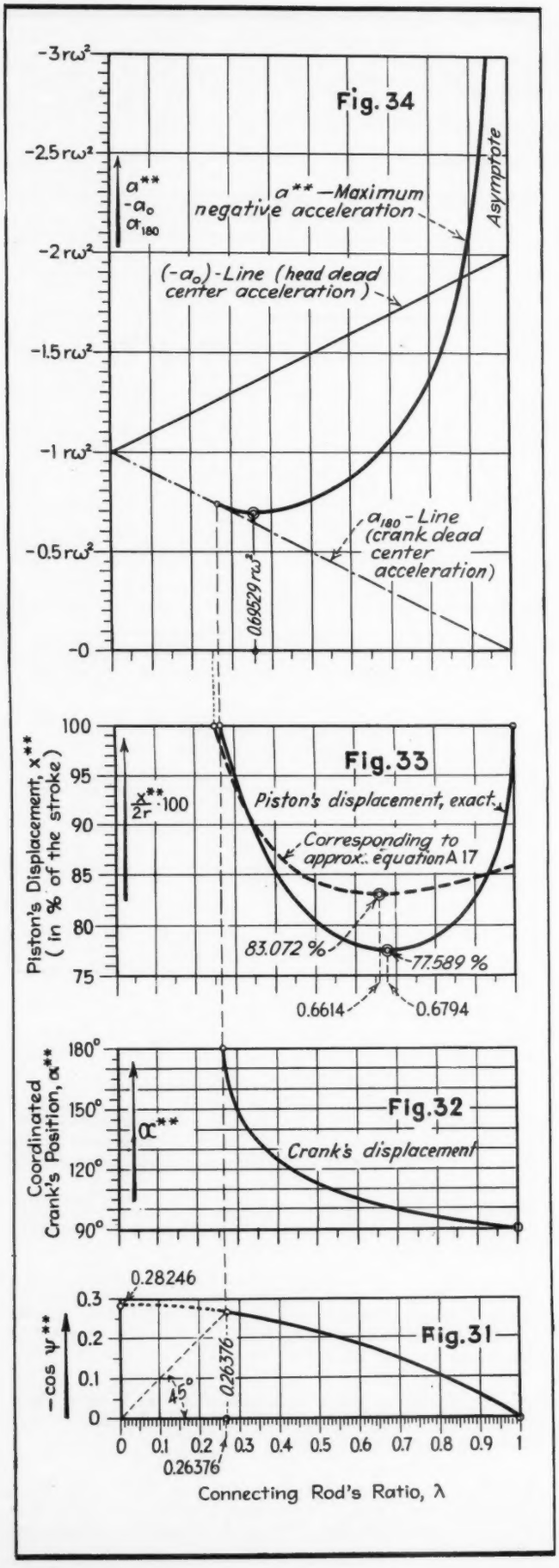
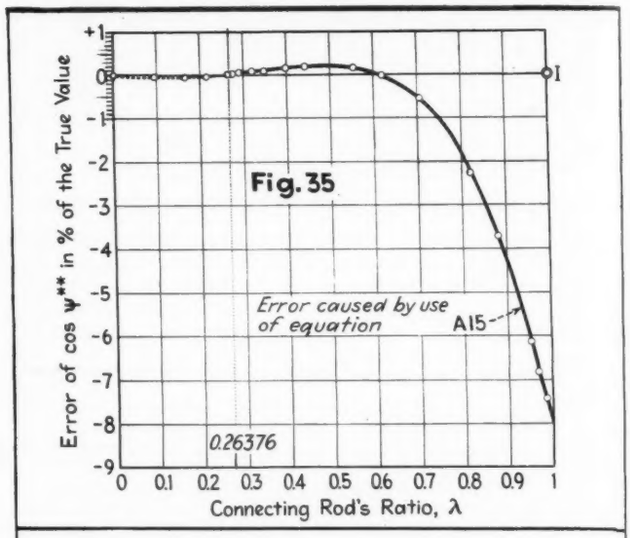
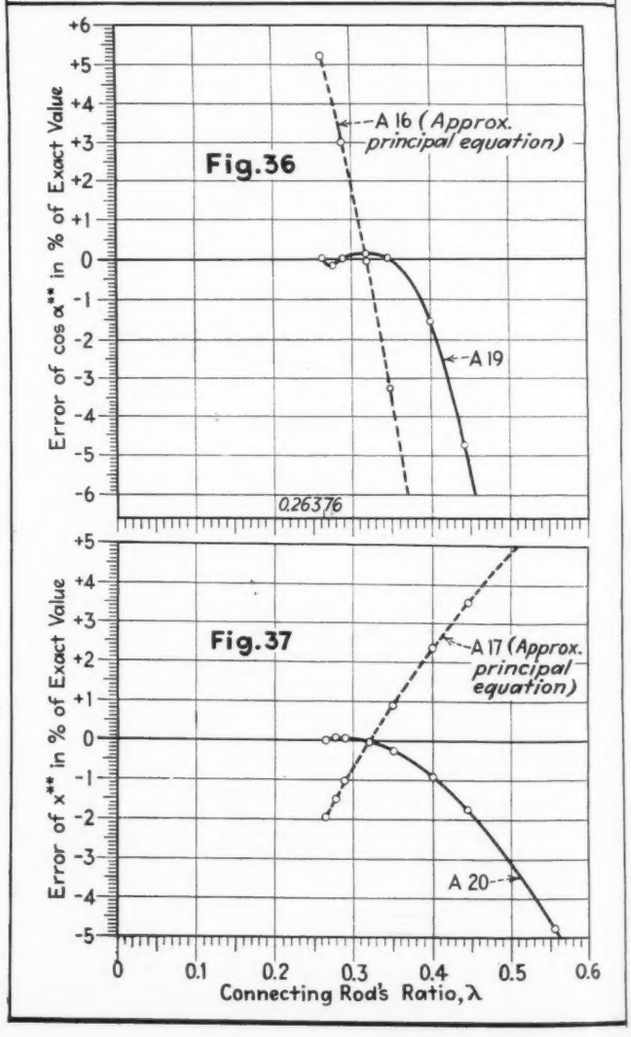


Fig. 31—Effect of λ on cos ψ^{**} at maximum negative piston acceleration is shown, corresponding to Equation (32). For λ = 0 to 0.26376 (dotted part of curve) the vertex S^{**} of the acceleration-displacement curve is outside the stroke, as will be shown at λ = 0.2 in Fig. 40, Part IV; even then S^{**} may be used to ascertain the shape of the latter curve

Fig. 32—Effect of λ on the crank position α^{**} for maximum negative acceleration is shown





other approximate principal equations (from Table II) in the following form:

$$x^* = r\left[(1 - \cos\alpha^*) + \frac{\lambda}{2}\sin^2\alpha^*\right] \quad \text{(A11)}$$

$$c_{max} = r \cdot \omega\left[\sin\alpha^* + \frac{\lambda}{2}\sin(2\alpha^*)\right] \quad \text{(A12)}$$

x^*, computed according to (A11) and (A10) is the abscissa to the zero ordinate of the Radinger parabola, Figs. 3 and 5.

3. New Formulas and Comparison:

The errors of the approximate principal equation (A10) are smaller than those of Equation (A7) for T-Position, so that (A10) may be satisfactory for many practical applications. Equation (A10) can be improved by adding $8\lambda^5$ under the root, which gives:

$$\cos\alpha^* = \frac{\sqrt{1 + 8\lambda^2 + 8\lambda^5} - 1}{4\lambda} \quad \text{(A13)}$$

In the usual range ($\lambda = 0$ to 0.35) the approximation of Formula (A13) is excellent. The error of α^* is nowhere greater than 0.12 percent of the true value, as shown by Fig. 28.

Principal equation (A11), too, is more accurate than the corresponding equation (A8) of the T-position, as indicated in Fig. 29. But the author's new equation:

$$x^* = r\,[0.85 + (0.4 - 0.8\lambda)^2] \quad \text{(A14)}$$

is not only much simpler, but also more accurate than (A11). In the most frequently used range ($\lambda = 0.2$ to 0.35) the greatest error is smaller than 0.09 percent of the true value of x^*. The error curves of Fig. 29, too, show the superiority of this formula.

While those T-position formulas involving the position of the mechanism proved inferior to the approximate principal equations, the contrary is true for the T-position formula (A9) for velocity, as shown by the error curves of Fig. 30. Within the above-mentioned range the accuracy of the simple formula (A9) is satisfactory.

Summarizing, the approximate formulas (A9) and (A14) are recommended particularly for practical use.

Maxima and Minima of Acceleration: are characterized by the expression:

$$\frac{da}{dt} = \frac{da}{dx} \cdot \frac{dx}{dt} = c \cdot \frac{da}{dx} = 0$$

with three solutions:

$c = 0$ (Two dead centers)

and $\frac{da}{dx} = 0$ (Maximum negative acceleration)

Since $\frac{da}{dx}$ is the slope of the acceleration curve ($\tan\delta$ in Fig. 1), this separation explains why the dead center vertices of the acceleration curve of Fig. 2 do not represent themselves as vertices (with horizontal tangents) in the corresponding points Q_0 and Q_{180} of the acceleration curve of Fig. 1.

The dead center accelerations a_0 and a_{180} can be easily computed by equations shown in Table VII.

Maximum Negative Acceleration

Exact Computation: The third apex S^{**} in Fig. 2 corresponds to the vertex S^{**} in Fig. 1. Therefore, by making $\frac{da}{dx} = 0$ in Equation (23), the equation becomes:

$$\cos^4\psi^{**} - \cos^3\psi^{**} - \cos^2\psi^{**} + \cos\psi^{**} = -\frac{1 - \lambda^2}{3} \quad (32)$$

Unfortunately, a simple general solution of this exact equation cannot be given when the ratio λ is a constant as in all practical cases. This makes necessary the development of approximate equations for practical use. These are discussed in the next section.

On the other hand, Equation (32) enables the computation of λ, if λ is not constant, and if ψ^{**} is the independent variable. Having ψ^{**}, it is easy to compute α^{**}, x^{**}, and a^{**} by using the exact principal equations in Table VI. In this way the curves of Figs. 31 to 34 were plotted. They show the influence of λ and reveal the basic facts established by analysis of the vertex S^{**}, the most important of which are:

1. The value $\lambda = 0.26376$ is a limiting value. At smaller values there can never be a second minimum of acceleration in addition to a_{180}.
2. For $\lambda < 0.26376$ the apex S^{**} of the acceleration curve (Fig. 2) disappears entirely.
3. For $\lambda < 0.26376$ (dotted range in Fig. 31) the apex S^{**} of the acceleration curve of Fig. 1 is located on an extension of the acceleration curve, as will be shown by the dotted curve Q_{180} .... S^{**} (at $\lambda = 0.2$) in Fig. 40 of Part IV. Such extension can be worthwhile for an exact construction of the non-extended part of the curve, but the ex-

Fig. 33—Effect of λ on piston displacement at maximum negative acceleration is shown. The dashed curve gives the piston displacement which belongs to the negative maximum of Radinger's Parabola (see Figs. 3 and 5). Its deviation between $\lambda = 0.25$ and 0.26376 is not noticed in the error curves of Figs. 36-38

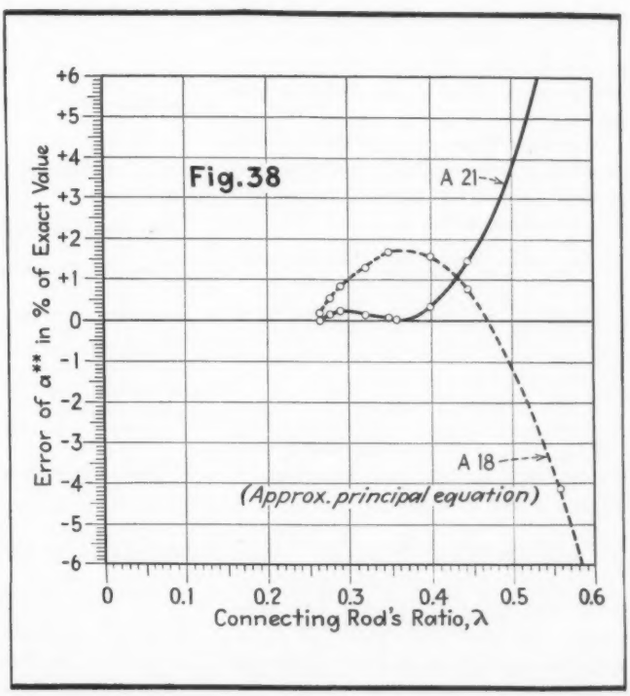
Fig. 34—Effect of λ on maximum acceleration a^{**}. In the range λ — 0 to 0.26376 where no vertex occurs, the dead center acceleration a_{180} (dashed-dotted line) is the greatest negative acceleration. The ($-a_0$) line shows greater values of acceleration than the a^{**} curve in most of the range

Fig. 35—Errors of cos ψ^{**} when using Equation (A15) for maximum negative acceleration. I is an "isolated point" of the error curve

Fig. 36—Errors of α^{**} when using Equation (A16) and (A19). The dotted curves in Figs. 36-38 show the errors occurring when the vertex of the Radinger Parabola is used instead of true maximum negative acceleration. The error curves of the new equations (solid lines) show much closer approximation

Fig. 37—Errors of x^{**} when using Equations (A17) and (A20)

Fig. 38—Errors of a^{**} when using Equations (A18) and (A21)



tended part would not mean the existence of any pistion motion within this extension.

4. At $\lambda = 0.26376$ the vertex S^{**} enters the unextended acceleration line at the crank end dead center Q_{180}, as will be shown in Fig. 40. The growth of maximum piston acceleration a^{**} with increasing λ — values may be studied in Fig. 34 as well as in Fig. 40.

5. For $\lambda > 0.88$ the acceleration a^{**} becomes greater than the head end dead center acceleration, a_o, which is usually computed as the greatest acceleration (important in computing strength). For still greater λ values, a^{**} grows rapidly, as shown in Fig. 34, until for $\lambda = 1$, a^{**} becomes infinite.

The exact values derived by the above-described computation of the curves made possible a check of the results of the approximate formulas.

Approximate Formulas:

1. Approximate Solution of Equation (32):

On the basis of the exact curves for $\cos \psi^{**}$, Fig. 31, the following approximation is suggested:

$$\cos\psi^{**} = A(1 + B \cdot \lambda^{2\cdot 2}) \cdot \cos(\lambda \cdot 90°) \quad \text{(A15)}$$

wherein the constants are

$$A = -0.28246 \text{ and } B = 0.37717.$$

The error curve, Fig. 35, for this equation shows a close approximation in the commonly used range between $\lambda = 0$ and $\lambda = 0.32$ where the deviation is smaller than 0.06 percent of the true value.

After $\cos \psi^{**}$ is obtained from Equation (A15) this value must be put into the exact main equations in Table VI in order to find α^{**}, x^{**}, and a^{**}. Hence, Equation (A15) is less convenient than the direct approximate formulas to follow.

The advantage of Equation (A15), however, is the possibility that it can be applied in a much greater range than that usually needed.

2. Formulas Based on the Approximate Principal Equations:

When $\frac{da}{dt} = 0$ in approximate Equation (A5):

$$\cos \alpha^{**} = \frac{-1}{4\lambda} \quad \text{(A16)}$$

When this value is introduced into the approximate principal equations of Table II, they become:

$$x^{**} = r\left(1 + \frac{\lambda}{2} + \frac{7}{32\lambda}\right) \quad \text{(A17)}$$

$$a^{**} = -r.\omega^2.\left(\lambda + \frac{1}{8\lambda}\right) \quad \text{(A18)}$$

Equations (A17) and (A18) give the ordinates of the minimum vertex of the Radinger parabola shown in Figs. 3 and 5.

The dotted lines in the error curves, Figs. 36–38, show the errors of Equations (A16) to (A18). While the deviations of x^{**} and a^{**} may be permissible for many practical cases in the usual range ($\lambda = 0.26376$–0.33), the deviations of $\cos \alpha^{**}$ are too great.

3. Approximations Derived from Exact Curves:

For greater accuracy the approximate Equations (A19–21), put together in Table IX, are given for the first time. Their error curves, drawn with solid lines in Figs. 36–38, show the superiority of these equations to Equations (A16–18), drawn with dotted lines.

Points of Inflection of Acceleration Curve

Unlike locating vertex S^{**}, the points of inflection of the acceleration curve can be located easily. The knowledge that their displacements ξ_{W_1} and ξ_{W_2} are constant multiples (given in Table X) of the fixed value f, comes from Vaes, whose work is referred to in Part II.

From the equations for computing ξ_W and ξ_{W_2} the surprisingly simple fact that the angles ψ_{W_1} and ψ_{W_2} of the fixed points are constant and independent of λ can be shown. This leads to the other simple expressions of Table X.

The location of the points of inflection determines the form of the curve. These points may be found either on the real acceleration curve in Fig. 20 or on one of its extensions, outside of the piston stroke (dotted lines). The latter cannot correspond to any real position of the mechanism. Consequently, by "occurrence" of points of inflection only those points occurring within the "real curve" are meant.

The analysis of the range of occurrence of points of inflection in Table X is of utmost importance. It shows that there is never a point of inflection in the usual range of λ. The acceleration curve, therefore, is concave downward in all practical cases.

For greater values of λ it is interesting to follow the varying location of W_1 and W_2 with increasing λ, as will be shown in Table XI and in Fig. 40 of Part IV.

Table IX—Close Approximate Equations for Maximum Negative Acceleration

(See vertex S** in Fig. 20; for deviations see error curves Figs. 36–38)
In Equation (A19) use the positive sign of root only.

	Approximate Equation	No.	Constants	
			A	B
Position of Crank.....	$\cos \alpha^{**} = A + B\sqrt{\lambda - 0.21317}$	(A19)	−1.4813	2.1398
Position of Piston.....	$x^{**} = r\left(1.228 - A\lambda + \frac{B}{\lambda}\right)$	(A20)	0.21429	0.21875
Acceleration of Piston....	$a^{**} = -r\omega^2[A + 4.69(B - \lambda)^2]$	(A21)	0.69529	0.35720

Table X—Points of Inflection of the Acceleration Curve

(See Fig. 20. Also Fig. 40 and Table XII in Part IV)

Point of Inflection	W_1	W_2
Range of Occurrence...	$\lambda \geqq 0.39039$	$\lambda \geqq 0.64039$
Angle of Fixed Point's Ray (independent of λ)	$\psi_{W_1} = 67° 1' 15''$	$\psi_{W_2} = 129° 49' 15''$
Piston's Displacement..	$\xi_{W_1} = 1.51022\, f$ $x_{W_1} = r + l - \xi_{W_1}$	$\xi_{W_2} = 0.46821\, f$ $x_{W_2} = r + l - \xi_{W_2}$
Piston's Acceleration...	$a_{W_1} = \xi_{W_1}\omega^2\left(1 - \frac{0.51669}{\lambda^2_f}\right)$	$a_{W_2} = \xi_{W_2}\omega^2\left(1 - \frac{0.96767}{\lambda^2_f}\right)$
Slope of $a - x$ Line....	$\tan \delta_{W_1} = -\omega^2\left(1 + \frac{0.60515}{\lambda^2_f}\right)$	$\tan \delta_{W_2} = \omega^2\left(\frac{1.85905}{\lambda^2_f} - 1\right)$

HYDRAULIC CIRCUITS - I

Selection of Controls for Typical Systems

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ENGINEERS customarily use the terms "hydraulic circuits" and "hydraulic pressure" when discussing machines that are operated either by oil or water for the pressure medium. This lack of definiteness as to the character of the medium sometimes leads to mistaken conceptions concerning the utility of the two fluids.

Even advertisements and trade literature frequently do not specifically state that the equipment may be suitable only for use with oil. It is not surprising, therefore, that inquiries are occasionally made as to whether certain equipment designed to operate with oil could be operated with water. Possibly this confusion could be eliminated by employing a more descriptive or accurate word to designate power developed by oil. Why not coin a new word, such as "Oildraulic," to describe more exactly the equipment designed solely for oil as the fluid medium?

Many machines, of course, may be operated with either water or oil for the pressure and displacement medium; but at the present time, a major portion of the equipment being built utilizes oil; water being used in special or a few isolated installations.

Systems using water have certain advantages. Where large volumes of the fluid medium are required the cost of oil may be prohibitive. Water, having a constant viscosity, is not affected to the extent that oil is by change in temperature.

Since most hydraulic pumps designed for water have a constant displacement, also since the presses in the system usually require large volumes of water under pressure only for short time intervals, accumulators are often included in the system as reservoirs to hold a quantity of water under pressure until needed by the presses. With this arrangement a pump can be installed which has a displacement capacity per minute approximately equal to the cross-sectional area of the press ram multiplied by the stroke of the press divided by the time interval in minutes between the press strokes. Without an accumulator, of course, the pump must have a volume displacement rate equal to the volume displacement rate of the press; in this arrangement the pump is usually of a much larger size than would be required if an accumulator was installed in the circuit.

The fluid pressure in the system cannot be readily varied, since the unit pressure is governed by the amount of weights or ballast on the accumulator's piston and the cross-sectional area of the piston. Consequently, the system operates at a maximum pressure determined by the accumulator; not by the resistance developed by the press operation which may be of a variable magnitude. While the accumulator is being filled the pump operates at a constant horsepower output.

During the work periods of the press, the falling velocity of the accumulator ram and weights is inversely proportional to the area of the accumulator piston and directly proportional to the area and velocity of the press ram. High press speeds, therefore, involve rapidly falling accumulators which when suddenly stopped by closure of the press results in shock to the pump, valves and piping in the system. To eliminate the surges of pressure, caused by the falling accumulator ballast coming to rest, shock absorbers must be used in the hydraulic system.

Since the introduction of the variable stroke radial piston pump in the United States in 1920, the use of oil as a fluid medium has grown rapidly because this type of pump was capable of supplying at high uniform pressures variable quantities of fluid as required by press or machine operations. So that at the present time, oildraulic machinery has largely replaced hydraulic machinery, except in special installations where fluid pressures greater than 3,000 lb. per sq. in. are required.

Oildraulic circuits have a further advantage in that they can be applied to practically all types of machines, regardless of the size or speed required. With the proper selection of pumping units, pressures as high as 3,000 lb. per sq. in. can be obtained. There may be certain installations where accumulators prove to be economically feasible in oildraulic circuits; but, if used, provision must still be made to reduce the shocks as much as possible.

In selecting controls for oildraulic circuits the designer must first decide on the type and capacity of pumping equipment to use. This is predicated on the tonnage required or the unit pressure, and the number of cycles in a given time period or pressing speed required for an operation.

Secondly, he must determine whether he will require continuous application of pressure, instantaneous application of maximum pressure, or gradual build-up of pressure.

Pumps for oildraulic service may be divided into two general types; constant displacement, and variable displacement.

There are two types of constant-displacement pumps; gear and vane. Some sizes in both types may be used for pressures up to 1,000 lb. per sq. in. Gear pumps may be obtained having capacities as high as 200 g.p.m. at pressures up to 300 lb. per sq. in. Usually, however, the capacities are limited to approximately 25 g.p.m. with pressures up to 500 lb. per sq. in. Vane type pumps are built in capacities up to 35 g.p.m. for pressures as high as 1,000 lb. per sq. in. Practically all low-pressure machine tool applications use gear or vane pumps.

There are three general types of variable-displacement pumps; vane, axial piston, and radial piston.

Variable-displacement vane type pumps are furnished only in capacities up to 25 g.p.m. operating at pressures up to 1,000 lb. per sq. in. maximum.

Axial piston pumps are suitable for use at pressures up to 1,500 lb. per sq. in., where exceptionally large capacities are required. They are used principally as transmissions; sizes up to 300 hp. may be obtained.

Radial piston pumps may be used for constant or variable-displacement service. They can be obtained with capacities up to 250 g.p.m. at pressures up to 3,000 lb. per sq.in. Radial piston pumps are used for all types of presses and machine tools. Their special value lies in their ability to provide variable discharge.

The simplest oildraulic circuit utilizes a single-acting ram which may be either the spring return or gravity return type. Single-acting rams using constant-displacement pumps require an operating valve and a relief valve as

shown in Fig. 1. In Fig. 1(*A*) a 3-way piston valve is indicated for the operating valve, however, as shown in Fig. 1(*B*) a by-pass valve could be used here instead. The ram can be operated by moving the spindle in the piston type valve, or by closing the by-pass valve if used. With a by-pass valve the speed of ram movement can be controlled by adjusting or regulating the amount of valve opening, the pressure created depending upon the resistance offered to the movement of the ram. The oil is by-passed under pressure, of course, and represents a loss in power which causes heating of the oil.

With this type of circuit, the electric motor must be large enough to carry the full capacity of the pump. Any ram speed less than that obtained by utilizing the full capacity of the pump will result in a loss of power. This loss of power is equal to the difference between the horsepower output of the pump and the horsepower delivered to the ram. Thus, if a 25 g.p.m. gear pump is used to supply oil to a 10 in. dia. ram, the ram speed would be approximately 7.3 in. per min. when the by-pass valve is completely closed. If the ram was required to move at say, 3 in. per min. the oil required by the ram would be 10.3 g.p.m. making it necessary to by-pass 25 — 10.3 or 14.7 g.p.m. This 14.7 g.p.m. at a pressure of 500 lb. per sq.in., therefore, represents a loss in mechanical energy of approximately 4.3 hp. Since 1 hp. is equal to 2,545 b.t.u. per hr., 4.3 hp. would be equivalent to a heat loss of approximately 183 b.t.u. per min. which is dissipated in raising the temperature of the oil.

If a variable-discharge pump was used, the pump could be adjusted to provide just the right amount of discharge to give the speed required and the loss in power with resultant heating of the oil would be eliminated.

When a single-acting ram is operated by a variable-displacement reversible pump, as shown in Fig. 2, neither a 3-way nor a by-pass valve is required, however, a relief valve should be included in the circuit to prevent overloading. When the ram is to be returned to its starting position, the pump discharge is reversed and the oil is sucked out of the ram cylinder. Of course, when the ram bottoms no more oil should be drawn from the cylinder to supply the pump with its suction. It is necessary, therefore, to provide a by-pass line and check valve connecting the pump suction and discharge, so that when the ram is bottomed the oil supply continues to by-pass through the pump without causing any damage because of poor lubrication.

Double-acting rams are used in practically all machine tool and many press applications. When used with constant-displacement pumps, as shown in Fig. 3, a 4-way operating valve is required. If the ram is vertically acting, either a foot valve or a back pressure speed control valve should be installed to prevent the ram from dropping of its own accord. This valve is simply the combination of a check valve and low-pressure relief valve adjusted to open at a low pressure. In order to cause downward movement of the ram, sufficient pressure must be created on the top side of the ram to overcome the resistance offered by the low-pressure relief valve. Consequently, the ram will always work down against a definite back pressure. On the ram return or up stroke, the check valve functions to permit free flow to the ram.

In many machine tool applications and in some press applications, a variation in the rate of movement of the ram is desirable. This may be accomplished by installing a speed control valve which is a combination of a throttle valve and check valve. The combination valve for speed control is installed in the pull back or return side of the ram as shown in Fig. 4. The speed is varied by changing the size of the orifice in the needle or throttle valve. If the orifice is closed, there can be no flow, and consequently no movement of the ram. As the valve is opened, a definite quantity of oil flows through, the amount depending upon the resistance or pressure created by the work.

To illustrate the functioning of the circuit shown in Fig. 4, assume that a machine requires a feed of 30 ft. per min. and the force to be overcome is 700 lb. Select a 3 in. dia. cylinder with a 2 in. dia. piston rod to give approxi-

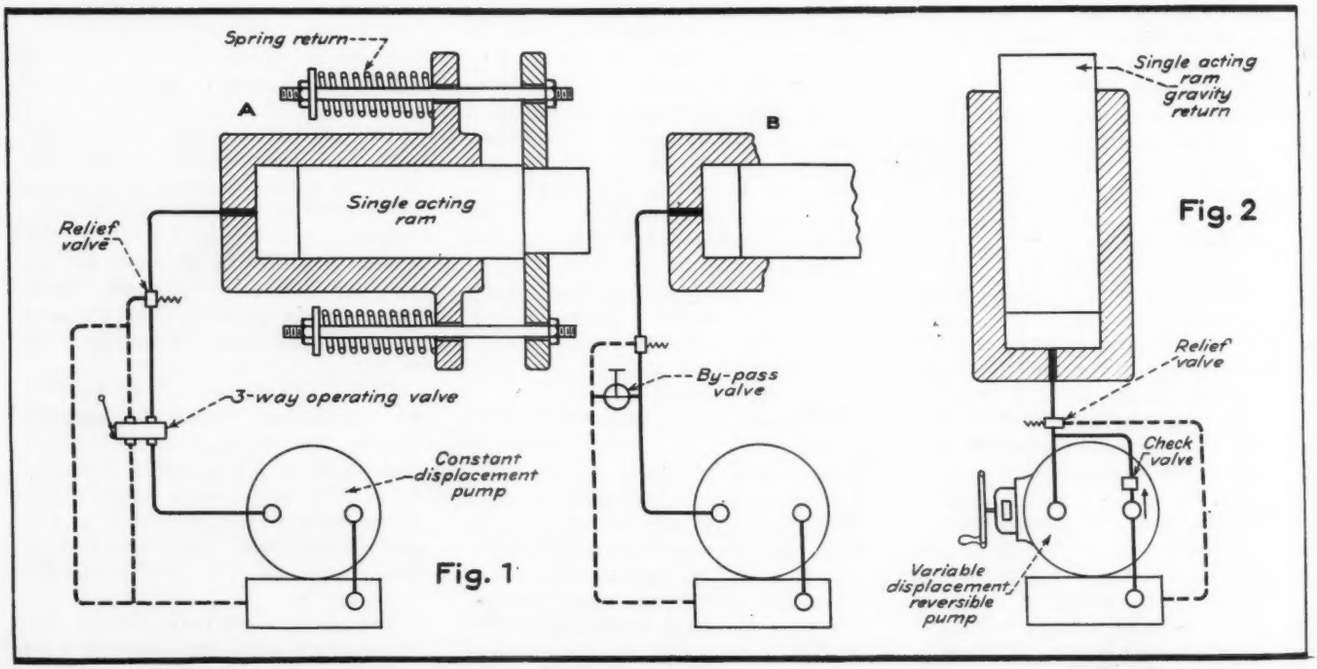

Fig. 1

Fig. 2

Fig. 1—(A), To the left, is shown a simple circuit for a single-acting ram with a spring return. At (B) is shown an optional arrangement which uses a by-pass valve for the control. Fig. 2—Method of controlling a single-acting ram with gravity return when pump is of the variable-displacement reversible type

mately a 2 to 1 ratio. The area of feed side would be 7.07 sq.in. and the area on the return or rapid traverse side would be 3.9 sq.in. Assume also that a 25 g.p.m. gear pump unit is provided, and that the relief valve is set at 300 lb. per sq.in. The diagram shows for the speed control units, a needle valve and check valve installed in the return side. These two valves are usually combined in one valve and can be obtained from several sources.

In order to obtain a feeding rate of 30 ft. per min., oil must be supplied to the feed side of the cylinder at the rate of 11.03 g.p.m. This will mean that the excess oil or the difference between the capacity of the pump, namely, 25 g.p.m. and 11.03 g.p.m., or 13.97 g.p.m. will be discharged through the relief valve at 300 lb. per sq.in. This, of course, represents a loss of power which is translated into heat and consequently the oil temperature in the reservoir is increased.

In order to develop a maximum force of 700 lb. on the piston rod with 300 lb. per sq.in. pressure on the feed side of the cylinder, the opening of the needle valve or speed control valve must be adjusted to create a back pressure at a flow rate of $(11.03 \times 3.9)/7.07 = 6$ g.p.m., approximately. The back pressure can be calculated in the following manner. The total hydraulic supply pressure on the feed side equals the total hydraulic back pressure on the return side plus the load on the work end of the piston rod, that is, the unit back pressure equals

$$\frac{7.07 \times 300 - 700}{3.93} = 360 \text{ lb. per. sq.in.}$$

The needle valve opening would, therefore, have to be adjusted to set up a resistance equal to this back pressure.

On the return stroke which is obtained by reversing the position of the 4-way valve, the oil would flow freely to the return side of the cylinder through the check valve. The return speed would be

$$\frac{25 \times 231}{3.93} = 1{,}470 \text{ in. per min.}$$

or approximately 120 ft. per minute.

It should be noted that this rapid rate of return requires that the oil be discharged from the work side of the cylinder at a rate of

$$1{,}470 \times \frac{7.07}{231} = 45 \text{ g.p.m.}$$

This rate of discharge should be checked as in some installations it may be necessary to increase the size of the pipe or valves in order to keep the velocity down to a reasonable figure.

One manufacturer has developed a line of control valves that have practically constant flow regardless of viscosity or pressure. Fig. 5 illustrates the comparative performance of an ordinary throttle needle valve and this constant flow control valve. With the ordinary needle valve, increased pressure causes increased flow, thus if constant flow is desired it is necessary to adjust the valve opening as the pressure changes. With the balanced control valve, the flow is practically uniform at all pressures.

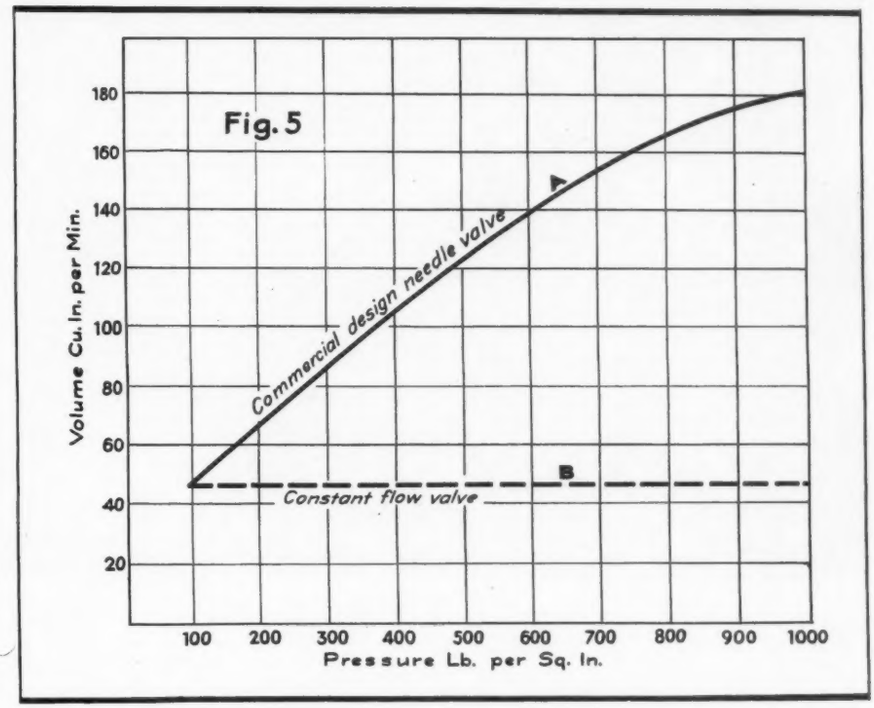

Fig. 5—Curve A shows the variation in flow through a typical needle valve as pressure increases. Curve B shows approximately constant flow through constant flow valve as pressure increases

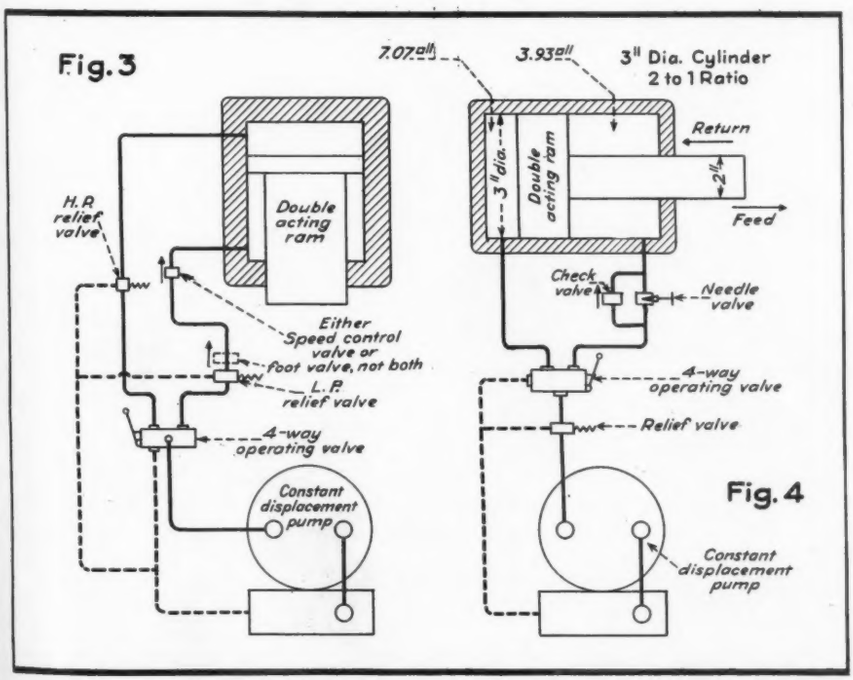

Fig. 3—Controls for vertical double-acting ram circuit which uses a constant-displacement pump. Fig. 4—Use of a speed control valve in circuit having a horizontal double-acting ram

Extrusion of copper-base tubing

COPPER-ZINC ALLOYS – I

Fabricating Characteristics and Physical Properties

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THE MOST WIDELY USED and the best known copper-base alloys are those of copper and zinc known as the brasses. As more zinc is added to copper, tensile properties increase, electrical and thermal properties decrease and some diminution of resistance to corrosion results.

Certain mill products and certain manufactured products may be produced at lower cost if, instead of copper, certain of the brasses are used. Cost frequently is the consideration which leads to the use of brass rather than copper for a given product. In general the brasses offer mechanical properties superior to those of copper; the advantage of brasses in this respect may be gained at a sacrifice of both electrical and thermal conductivities.

There are two broad classifications of the alloys of copper and zinc; one containing from 64 percent to 100 percent copper, consisting of a single phase and known as alpha brasses, and the other containing from 55 percent to 64 percent copper containing two phases and known as the alpha-beta brasses. In the alloys of copper and zinc containing less than 55 percent copper, the beta phase predominates and the alloys are brittle and of no commercial significance.

Alpha Brasses

The alpha brasses are exceptionally ductile and malleable at room temperature and can be cold worked by deep drawing, spinning, stamping, forming, cold rolling, cold heading, flaring and upsetting. As the brasses are cold worked they become increasingly hard. The degree of hardness is dependent on the amount of cold working and the copper content of the alloy. The alpha brasses containing in excess of 85 percent copper have work hardening properties similar to copper. Those containing between 64 and 85 percent copper work harden less rapidly than those of higher copper content. Because of this property these brasses are used extensively for applications requiring successive drawing operations without intermediate anneals.

After cold working, the brasses can be rendered malleable or ductile again

by heat-treatment at temperatures ranging from 700 deg. F. to 1,400 deg. F., depending upon the properties desired. Since the alpha brasses are single-phase alloys they cannot be hardened with a heat-treatment.

Alpha brasses containing between 64 percent and 80 percent copper possess relatively poor hot-working properties. In order to hot roll or hot forge these alloys successfully, utmost care must be taken to keep lead, a natural impurity of most zinc, to a trace, as the presence of even 0.03 percent of lead will cause these alloys to crack at any hot-working temperature. Brasses of this group are best hot worked at temperatures in excess of 1,350 deg. F. and the best results are secured if all hot working is done within the 1,350–1,550 deg. F. range.

The alpha brasses containing 80 percent more copper have hot-working properties comparable to those of copper, which is extremely plastic through a wide temperature range. However, as in the case of copper, the lead content must be controlled within close limits. As a general rule, if these brasses do not contain in excess of 0.03 percent of lead they can hot forged, hot rolled, or otherwise hot worked without any difficulty.

In the alpha range, tensile properties increase with increase of zinc content. This is also accompanied by a color change from red through gold to the

Table I—Gilding Metal

Copper 95 percent – Zinc 5 percent

Property	Hard (1)	Soft (2)	Units
Tensile strength (3)	58–63	36–38	1,000 lb. per sq. in.
Elongation (3)	4	45	Percent in 2 in.
Elastic limit (3)	48–55	5–9	1,000 lb. per sq. in.
Rockwell hardness B (3)	64–71	53–62 (4)	1/16 in. ball–100 kg. load
Young's modulus of elasticity	15,000,000		Lb. per sq. in.
Melting point	1,950		Deg. F.
Density	0.320		Lb. per cu. in.
Coefficient of expansion	0.0000181		Per deg. C. from 25–300 deg. C
Electrical conductivity	54.6		Percent I.A.C.S.–68 deg. F.
Thermal conductivity	139.5		B.t.u. per sq. ft. per hr. per ft./deg. F.

(1) 6# hard — 0.015–0.070 grain size at ready to finish respectively.
(2) Refer to 900 deg. F. anneal (one hour at temperature).
(3) Apply to strip only (all tests conducted on 0.040 in. stock).
(4) Rockwell F — 1/16 in. ball — 60 kg.

Table II—Commercial Bronze

Copper 90 percent – Zinc 10 percent

GENERAL DATA — ROD

Property	Rod		Forgings			Units
	Hard (1)	Soft	Hot	Cold (2)	Cold (3)	
Tensile strength	65	35	35–40	40–65	65	1,000 lb. per sq. in.
Apparent eleastic limit	54	7	7–10	20–52	54	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	60	18	12–15	25–58	60	1,000 lb. per sq. in.
Yield strength 0.20 percent "offset"	63	11	11–13	25–61	63	1,000 lb. per sq. in.
Yield strength 0.10 percent "offset"	60	10	10–12	20–55	60	1,000 lb. per sq. in.
Elongation	18	56	60–50	48–19	19	Percent in 2 in.
Reduction of area	75	82	90–80	82–75	75	Percent
Endurance limit	18	12		12–16	18	1,000 lb. per sq. in.
Modulus of elasticity			15,000,000			Lb. per sq. in.
Rockwell F	97	55	50–60	69–97	97	60 kg.— 1/16 in. ball
Rockwell B	68			65	67	100 kg.— 1/16 in. ball
Brinell	107	52		62–102	103	500 kg.— 10 mm. ball
Hot forging range			1,300–1,450			Deg. F.
Hot forging quality			good			
Type structure			single phase — alpha			

GENERAL DATA — STRIP

Property	Hard (4)	Soft (5)	Units
Tensile strength (6)	64–69	36–39	1,000 lb. per sq. in.
Elongation (6)	5	45	Percent in 2 in.
Elastic limit (6)	53–57	8	1,000 lb. per sq. in.
Rockwell hardness B (6)	72–76	56 (7)	1/16 in. ball—100 kg.
Young's modulus of elasticity	15,000,000		Lb. per sq. in.

PHYSICAL DATA

Melting point	1,913	Deg. F.
Coefficient of expansion	0.0000182	Per deg. C. from 25–300 deg. C.
Electrical conductivity	40.9	Percent I.A.C.S.
Thermal conductivity	108	B.t.u. per sq. ft. per hr. per ft. per deg. F.
Density	0.318	Lb. per cu. in.

(1) Refers to rod cold drawn 50 percent; rod under 1 in. diameter.
(2) Material cold forged from soft rod (5–40 percent reduction of area).
(3) Material cold forged from cold worked condition (40 percent).
(4) 6# hard — 0.070–0.015 mm. grain size at ready to finish respectively.
(5) Refer to 1,000 deg. F. anneal (one hour at temperature).
(6) Refer to strip only (all tests conducted on 0.040 in. stock).
(7) Rockwell F — 1/16 in. ball — 60 kg.

green yellows, and a progressive diminution of electrical and thermal conductivities.

Alpha brasses are, for the most part, adversely affected by the same substances and the same conditions that have an adverse effect on copper. In many instances they may be corroded by substances, particularly those which might be termed active chemical reagents, which do not affect copper to any appreciable extent. An exception to this generality is that for resisting the corrosive attack of sulphides, the brasses are better than copper; their superiority in that respect becomes more marked as the zinc content increases. In combating the corrosion of sea water 85/15 brass (known as "rich low" or "red brass") gives materially better service than copper itself.

Brass which contains less than 85 cent copper when exposed to certain media frequently fail in a characteristic manner termed "dezincification." Failures of this kind are identified by the appearance of spongy areas of copper in the form of layers or so-called "plugs" on the affected surface. This spongy copper is a consequence of the solution of fractions of the alloy in the media and a redeposition of the copper by chemical displacement. Arsenic, antimony and phosphorous in small fractional percentages are demonstrably effective in repressing or inhibiting dezincification in the alpha brasses.

Brass which contains less than 85 percent of copper may under certain conditions fail by stress-corrosion cracking, commonly called "season cracking." Conditions which favor this form of failure are the presence of internal stress produced by cold-working operations and exposure to mild atmospheric corrosion. The presence of traces of ammonia in the atmosphere is said to favor this form of corrosion. This form

Table III—Rich Low Brass (Red Brass)

Copper 85 percent – Zinc 15 percent

GENERAL DATA — ROD

Property	Rod		Forgings			Units
	Hard (1)	Soft	Hot	Cold (2)	Cold (3)	
Tensile strength	75	37	37–42	42–68	72	1,000 lb. per sq. in.
Apparent elastic limit	60	8	8–12	18–50	56	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	64	14	14–18	25–57	67	1,000 lb. per sq. in.
Yield strength 0.20 percent " offset "	72	14	14–16	22–54	68	1,000 lb. per sq. in.
Yield strength 0.10 percent " offset "	67	12	12–15	24–62	62	1,000 lb. per sq. in.
Elongation	55	18	60–50	47–20	18	Percent in 2 in.
Reduction of area	80	72	85–80	80–74	72	Percent
Endurance limit	20	14		14–18	20	1,000 lb. per sq. in.
Modulus of elasticity			15,000,000			Lb. per sq. in.
Rockwell F	100	59	48–68	70–98	100	60 kg.–1/16 in. ball
Rockwell B	78		18	75	78	100 kg.–1/16 in. ball
Brinell	126	54	60	63–120	126	500 kg.–10 mm. ball
Hot forging range			1,300–1,450			Deg. F.
Hot forging quality			good			
Type structure			single phase — alpha			

GENERAL DATA — STRIP

Property	Hard (4)	Soft (5)	Units
Tensile strength (6)	74–82	38–40	1,000 lb. per sq. in.
Elongation (6)	4	43	Percent in 2 in.
Elastic limit (6)	52–63	7–8	1,000 lb. per sq. in.
Rockwell hardness B (6)	82–86	10	1/16 in. ball–100 kg.
Young's modulus of elasticity	15,000,000		Lb. per sq. in.

GENERAL DATA — TUBE

Property	Hard (7)	Soft (8)	Units
Tensile strength	89	45	1,000 lb. per sq. in.
Elongation	4	43	Percent in 2 in.
Elastic limit	85	15	1,000 lb. per sq. in.
Rockwell hardness F	108	60	1/16 in. ball–60 kg.

PHYSICAL DATA

Melting point	1,870		Deg. F.
Coefficient of expansion	0.0000187		Per deg. C. from 25–300 deg. C.
Electrical conductivity	37.0		Percent I.A.C.S.
Thermal conductivity	82.2		B.t.u. per sq. ft. per hr. per ft. per deg. F.
Density	0.316		Lb. per cu. in.

AVAILABLE CREEP DATA

(hot rolled to 0.750 in. diameter; grain size 0.030 mm.)

		Rate of Creep Percent Per 1,000 Hr.		
		0.01	0.10	1.00
Temp. Deg. F.	No Measurable Flow	Stress to Produce Designated Rate of Creep		
400	up to 7,500	8,800	12,000	17,000
600	approaching zero	1,000	2,600	6,800

(1) Refers to rod cold drawn 50 per cent; rod under 1 inch diameter.
(2) Material cold forged from soft rod (5–40 percent reduction of area).
(3) Material cold forged from cold worked condition (40 percent).
(4) 6# hard — 0.070–0.015 grain size at ready to finish respectively.
(5) Refer to 1,100 deg. F. anneal (one hour at temperature).
(6) Apply to strip only (all tests conducted on 0.040 in. stock).
(7) Extruded, reduced, and cold drawn to 3/4 in. x 0.049 in.
(8) 950 deg. F. anneal for one hour.

Table IV—Low Brass

Copper 80 percent – Zinc 20 percent

GENERAL DATA — ROD

Property	Rod		Forgings			Units
	Hard (1)	Soft	Hot	Cold (2)	Cold (3)	
Tensile strength	75	44	42–48	47–80	85	1,000 lb. per sq. in.
Apparent elastic limit	52	9	7–14	20–50	55	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	56	13	10–19	25–58	65	1,000 lb. per sq. in.
Yield strength 0.10 percent " offset "	59	12	9–17	20–65	80	1,000 lb. per sq. in.
Yield strength 0.20 percent " offset "	68	13	10–19	25–70	85	1,000 lb. per sq. in.
Elongation	18	65	65–58	30–15	15	Percent in 2 in.
Reduction of area	70	80	82–80	80–65	60	Percent
Endurance limit	22	15				1,000 lb. per sq. in.
Modulus of elasticity			15,000,000			Lb. per sq. in.
Rockwell F	103	60	45–70	70–104	105	60 kg.— 1/16 in. ball
Rockwell B	80	9	24	81	82	100 kg.— 1/16 in. ball
Brinell	130	56	63	63–133	135	500 kg.— 10 mm. ball
Forging range			1,250–1,450			Deg. F.
Forging quality			good			
Type structure			Single phase — alpha			

GENERAL DATA — STRIP

Property	Hard (4)	Soft (5)	Units
Tensile strength (6)	91	46	1,000 lb. per sq. in.
Elongation (6)	6	49	Percent in 2 in.
Elastic limit (6)	69	13	1,000 lb. per sq. in.
Rockwell hardness B (6)	89	62 (7)	1/16 in. ball — 100 kg. load
Young's modulus of elasticity	15,000,000		Lb. per sq. in.

GENERAL DATA — TUBE

Property	Hard (8)	Soft (9)	Units
Tensile strength	98	48	1,000 lb. per sq. in.
Elongation	2	43	Percent in 2 in.
Elastic limit	76	19	1,000 lb. per sq. in.
Rockwell hardness F	109	58	1/16 in. ball — 60 kg.

PHYSICAL DATA

Melting point	1,832	Deg. F.
Coefficient of expansion	0.0000191	Per deg. C. from 25–300 deg. C.
Electrical conductivity	32.5	Percent I.A.C.S.
Thermal conductivity	81	B.t.u. per sq. ft. per hr. per ft. (deg. F.)
Density	0.313	Lb. per cu. in.

(1) Refers to rod cold drawn 37 percent; rod under 1 inch diameter.
(2) Material cold forged from soft rod (5–40 percent reduction of area).
(3) Material cold forged from cold worked condition (40 percent).
(4) #6 hard — 0.015 mm. grain size at ready to finish.
(5) Cold rolled #4 -- refer to 1,000 deg. F. anneal.
(6) Apply to strip only (all tests conducted on 0.040 in. stock).
(7) Rockwell F — 1/16 in. ball — 60 kg.
(8) Cold drawn to 13/16 in. x 0.049 in.
(9) Refer to 1,000 deg. F. anneal.

Table V—Spring Brass

Copper 75 percent – Zinc 25 percent

GENERAL DATA — STRIP

Property	Hard (1)	Soft (2)	Units
Tensile Strength	84–97	45–49	1,000 lb. per sq. in.
Elongation	5–7	58–66	Percent in 2 in.
Elastic limit	64–68	6–13	1,000 lb. per sq. in.
Endurance limit	21	17	1,000 lb. per sq. in.
Rockwell hardness F	107–110	57–61	1/16 in. ball — 60 kg. load
Rockwell hardness B	86–93	2–7	1/16 in. ball — 100 kg. load
Rockwell hardness G	59–71		1/16 in. ball — 150 kg. load
Rockwell superficial " 15-T "	89–91	62–63	1/16 in. ball — 15 kg. load
Rockwell superficial " 30-T "	74–78	17–20	1/16 in. ball — 30 kg. load
Young's modulus of elasticity	14,000,000	18,000,000	Lb. per sq. in.
Melting point	1,795		Deg. F.
Density	0.310		Lb. per cu. in.
Coefficient of expansion	0.0000196		Per deg. C. from 25–300 deg. C.
Electrical conductivity	30.0		Percent I.A.C.S. at 20° C.
Thermal conductivity	75		B.t.u. per hr. per sq. ft. per deg. F. per ft.

(1) #6 hard, 0.095–0.015 mm. grain size at ready to finish respectively. (2) Hard material (1) after 1,300 deg. F. anneal for one hour.

Table VI—70/30 or Cartridge Brass

Copper 70 percent – Zinc 30 percent

GENERAL DATA — ROD

Property	Rod		Forgings		Units
	Hard (1)	Soft	Cold (2)	Cold (3)	
Tensile strength	100	48	55–90	98	1,000 lb. per sq. in.
Apparent elastic limit	67	22	28–60	65	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	64	38	42–60	64	1,000 lb. per sq. in.
Yield strength 0.10 percent " offset "	63	34	37–62	62	1,000 lb. per sq. in.
Yield strength 0.20 percent " offset "	75	38	42–70	74	1,000 lb. per sq. in.
Elongation	14	55	50–15		Percent in 2 in.
Reduction of area	60	75	73–62		Percent
Endurance limit	22	17			1,000 lb. per sq. in.
Modulus of elasticity		15,000,000			Lb. per sq. in.
Rockwell F	108	75	88–105	108	60 kg.— 1/16 in. ball
Rockwell B	89	34	56–85	89	100 kg.— 1/16 in. ball
Brinell	154	70	90–142	154	500 kg.— 10 mm. ball

GENERAL DATA — STRIP

Property	Hard (4)	Soft (5)	Units
Tensile strength (6)	86–97	45–48	1,000 lb. per sq. in.
Elongation (6)	4	58–64	Percent in 2 in.
Elastic limit (6)	69–81	13	1,000 lb. per sq. in.
Rockwell hardness B (6)	88–93	15–20	1/16 in. ball — 100 kg.
Endurance limit (6) (at 10^8 reversals)			
Soft	16.5		1,000 lb. per sq. in.
4# hard	19.0		1,000 lb. per sq. in.
8# hard	22.0		1,000 lb. per sq. in.
Young's modulus of elasticity	15,000,000		Lb. per sq. in.

GENERAL DATA — TUBE

Property	Hard (7)	Soft (8)	Units
Tensile strength	95	51	1,000 lb. per sq. in.
Elongation	7	52	Percent in 2 in.
Elastic limit	90	13	1,000 lb. per sq. in.
Rockwell hardness F	110	59	1/16 in. ball — 60 kg.

PHYSICAL DATA

Melting point	1,750	Deg. F.
Coefficient of expansion	0.0000199	Per deg. C. from 25–300 deg. C.
Electrical conductivity	27.6	Percent I.A.C.S.
Thermal conductivity	70	B.t.u. per sq. ft. per hr. per ft. per deg. F.
Density	0.308	
Type structure	single phase — alpha	

AVAILABLE CREEP DATA

(hot rolled to 0.875 in. diameter, cold drawn to 0.750 in. diameter)

		Rate of Creep Percent Per 1,000 Hr.		
		0.01	0.10	1.00
Temp. Deg. F.	No Measurable Flow	Stress to Produce Designated Rate of Creep		
400	up to 10,000	12,700	18,000	27,000
600	approaches zero	290	850	2,150
800	approaches zero		approaches zero	

(1) Refers to rod under 1 in. diameter and rod cold drawn 50 percent.
(2) Material cold forged from soft rod (5–40 percent reduction of area).
(3) Material cold forged from cold worked condition (40 percent).
(4) 6# hard — 0.070–0.015 grain size at ready to finish respectively.
(5) Refer to 1,100 deg. F. anneal (one hour at temperature).
(6) Apply to strip only (all tests conducted on 0.040 in. stock).
(7) Extruded, reduced, and cold drawn to 3/4 in. x 0.049 in.
(8) 1,000 deg. F. anneal for one hour.

of attack can be effectively prevented by relief annealing below the recrystallization temperature.

A type of failure closely associated with "season cracking" and known as "fire cracking," occurs when susceptible brasses in a stressed condition are suddenly exposed to elevated temperatures. The presence of some lead in the brass decreases the resistance to this type of failure by promoting greater intercrystalline weakness. To avoid this form of failure it is common practice to bring stressed materials up to the annealing temperature gradually.

In the fabrication of susceptible alloys it is common practice to flex or spring them prior to annealing. The flexing or spring operation sets up balancing stresses to counteract the tensile stresses produced during fabrication.

The important commercial alpha brasses, in the order of increasing amounts of zinc, are: Gilding Metal; Commercial "Bronze"; Rich Low Brass; Low Brass; Spring Brass; 70/30 or Cartridge Brass; Deep Drawing Brass; Common Hi Brass (2 and 1); Tubular Rivet Brass; Brass Rod.

Gilding Metal—The alloy of copper and zinc, containing 95 per cent copper and known as gilding metal, is an extremely easy alloy to cold work. It flows readily in the intricate dies used for jewelry, emblems, plaques and coining operations. It can be readily spun, drawn, forged and upset. Its hot-working properties are comparable to those

of copper. This alloy has slightly higher tensile properties and about the same ductility as copper, but thermal and electrical properties are lower. This allow is commercially available in all common wrought forms.

COMMERCIAL BRONZE—Brass with 90 percent of copper, through long usage, has become known as commercial "bronze." It has excellent cold-working properties and can be readily spun, drawn, forged and upset. Its hot-working properties are similar to those of copper. Commercial bronze is used in the manufacture of custom jewelry, compacts, weather stripping, stamped hardware, forgings, screws, rivets, and various ammunition components. The alloy is fabricated as sheet, strip, plate, rod, wire, bar and tube.

RICH LOW BRASS or red brass has excellent cold-working properties and can be cold worked to a greater extent than copper because it has a better combination of strength and ductility. It is widely used for severe cold drawing, stamping or spinning operations. Red brass is not usually hot rolled or forged because, unlike the higher copper brasses, it is less plastic at elevated temperature. In the presence of a small amount of lead it is subject to cracking. Red brass containing less than 0.02 percent of lead can, however, be hot worked commercially at temperatures in excess of 1,350 deg. F. Red brass has excellent corrosion-resisting properties; in many cases superior to those of copper. When in contact with salt or brackish waters it offers better resistance than copper itself and it is used successfully under conditions of operation which cause the higher zinc alloys to fail through dezincification. Rich low brass is used extensively in the construction of automotive radiators; in the manufacture of tube and pipe for oil refineries and utilities, and in the field of domestic and industrial plumbing. This alloy is commonly fabricated in sheet, strip, plate, rod, bar and wire and tube.

LOW BRASS has hot and cold-working properties similar to rich low brass. Corrosion-resisting properties are generally the same as those of the latter. Under certain severe conditions it may dezincify or fail by season cracking. This alloy is used for flexible hose, bellows, clock dials, and numerous drawn and stamped parts and is usually fabricated in sheet, strip, rod, wire, bar and tube forms.

SPRING BRASS, containing 75 percent copper, has excellent cold-working properties and can be readily fabricated by spinning, drawing, forging and upsetting. It is not generally hot worked as its hot plastic range is extremely narrow. Spring brass is suitable for forming into springs were loads are not excessive and where corrosion resistance is important.

HIGH BRASSES, which include 70–30 or Cartridge Brass, Deep-Drawing, 2 and 1 and Common Hi Brass, possess the optimum combinations of strength and ductility. They all have excellent cold-working properties and can be readily spun, drawn, forged and upset. As a general rule they are not fabricated by hot-working processes as the range in which they are hot plastic is narrow.

Since the operations in which these allows are used require excellent ductility, those elements which have an adverse influence on this property must be carefully controlled. Iron, because of its hardening action, and lead, because of its influence on fire-cracking, are usually limited to 0.05 percent maximum. Such impurities as phosphorus, antimony, bismuth, nickel, chromium and aluminum are kept to a trace or less. Since alloys in this copper range are susceptible to "season cracking," it is common practice to relief anneal, at low temperatures, formed parts which are to be used under conditions of mild corrosion.

High brasses are used for the manufacture of pins, rivets, eyelets, snap-fasteners, automobile radiator cores, heating units, musical instruments, automobile lamp bodies and reflectors, cartridge cases and clips, electrical sockets, lamp bases, and many other drawn or formed shapes. High brasses are available in sheet and strip, rod, wire, bar and tube. The tables on Deep Drawing Brass, Common Hi Brass, Tubular Rivert Brass and Brass Rod will be presented in Part II of this series of articles on copper alloys.

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DESIGN OF SWING CAMS

PAUL E. RUDBECK

SWING CAMS properly designed to actuate limit switches, precision switches, hydraulic valves, or mechanical devices often are the simplest means for stop-start control of reciprocating machine elements. Principles involved in the design of these swing cams are generally simple and can best be brought out in this specific example.

The tool slide of a vertical hydraulic shaving machine should be allowed to take a few clean-up strokes after the table has reached the limit of feed. When the tool is brought to a stop, it should always be in the "up" position so that it does not interfere with loading and unloading.

To achieve this, the designers of this machine worked out an interlocked electrical-hydraulic system which, when table feed is shut off by the table stop dogs, energizes a time-delay relay. When the time delay runs out, a limit switch mounted beside the tool-holder slide is energized. This limit switch is actuated by a cam at every stroke of the tool; thus on the stroke immediately following its energization, it is actuated to shut off the power and stop the tool.

In the first design, Fig. 1, the cam was rigid and actuated the limit switch on both the up and down-strokes of the tool-holder slide when the work stroke was long. Thus, if the limit switch should be energized while the slide is up, current will be shut off on the down-stroke, and the slide will come to rest in the "down" position.

Various stages in the design of a swing cam to correct this situation are shown in Figs. 2, 3 and 4. Minimum slide stroke is ½ in., maximum stroke is 3 in., and maximum speed is 175 cycles per minute.

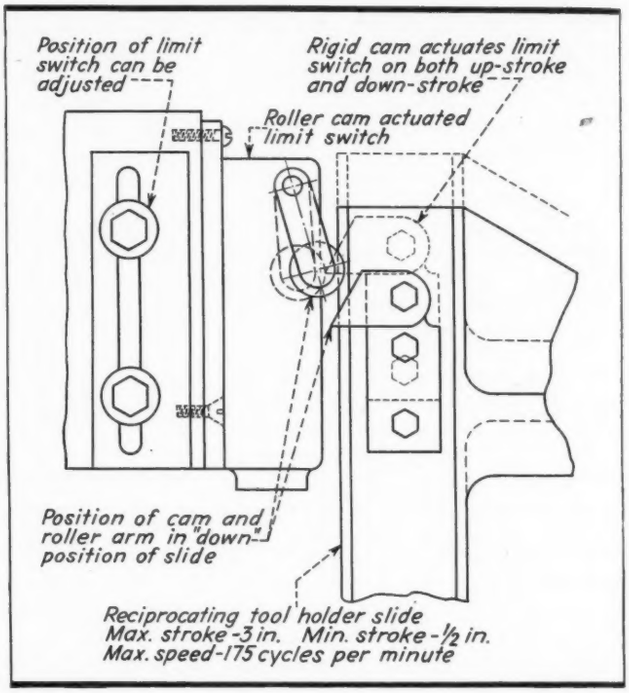

Position of limit switch can be adjusted
Rigid cam actuates limit switch on both up-stroke and down-stroke
Roller cam actuated limit switch
Position of cam and roller arm in "down" position of slide
Reciprocating tool holder slide
Max. stroke-3 in. Min. stroke-½ in.
Max. speed-175 cycles per minute

Fig. 1—First cam design was rigid and often resulted in tool stopping in "down" position, interfering with loading

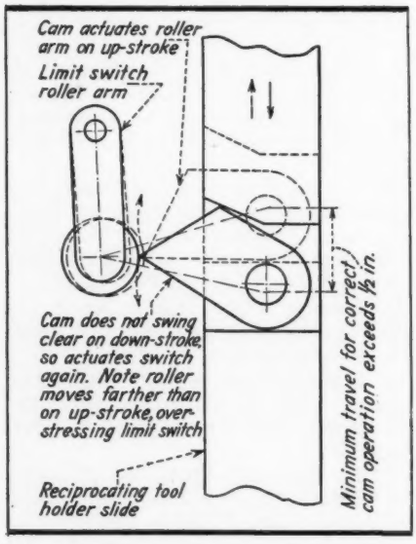

Cam actuates roller arm on up-stroke
Limit switch roller arm
Cam does not swing clear on down-stroke, so actuates switch again. Note roller moves farther than on up-stroke, overstressing limit switch
Reciprocating tool holder slide
Minimum travel for correct cam operation exceeds ½ in.

Fig. 2—Simple swing cam first designed could not swing clear of roller arm on down-stroke. Hence limit switch was actuated on both up and down-strokes, causing same trouble as in Fig. 1. Actually, on down-stroke the cam depressed the roller arm farther than on up-stroke, overstressing the switch. Also, cam did not function when stroke of tool slide was less than 1 in.

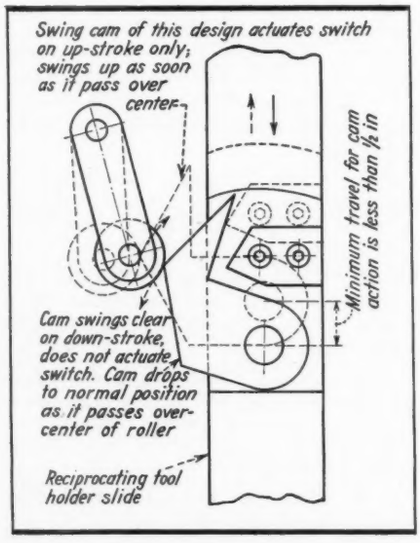

Swing cam of this design actuates switch on up-stroke only; swings up as soon as it pass over center
Minimum travel for cam action is less than ½ in
Cam swings clear on down-stroke, does not actuate switch. Cam drops to normal position as it passes over-center of roller
Reciprocating tool holder slide

Fig. 3—This cam, incorporating only a few design changes from that of Fig. 2, worked quite satisfactorily with the roller arm limit switch. The cam would swing free on the down stroke, falling into normal position as soon as its point passed over center of the roller. On up-stroke the switch was actuated, bringing the tool slide to rest in the "up" position as soon as switch was energized

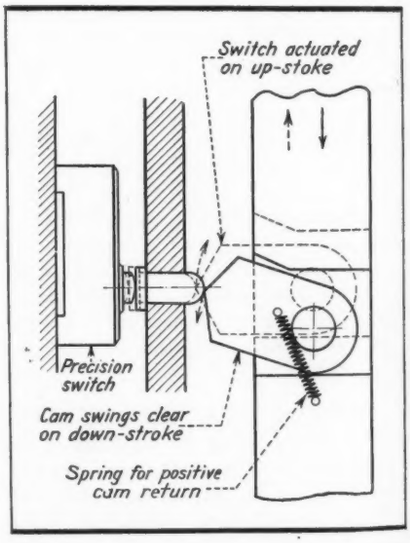


Fig. 4—For more accurate cam action with tool travel safely under ½ in., this design is proposed. Instead of using a limit switch, the cam operates a precision switch requiring only slight cam action. A switch with considerable overtravel should be specified to prevent damage which might be caused by errors in set-up. A spring supplements gravity cam return for positive, fast action

Question and Comment

Reviews Article on "Bending Stresses In Materials Having Dissimilar Elastic Moduli"

ROBERT E. BRUCKNER
Kimble Glass Company

These comments refer to the article appearing on pages 290 to 292 of PRODUCT ENGINEERING for June, in which Mr. William I. Powell contributes an original attack on the problem, "Bending Stresses in Materials Having Dissimilar Elastic Moduli." Due to the importance of this subject, his premises and derivation were reviewed in detail and appear entirely correct.

While none of the references investigated by the present writer denied existence of different moduli of elasticity for tension and compression, no other test data was discovered. It might be that engineers have been taking it too much for granted that the elastic modulus in compression was equal to that in tension. The writer feels that Mr. Powell should tell us how many tests on what composition of manganese bronze supported the surprising fact of dissimilar moduli.

The following comments should assist other engineers in quickly understanding Mr. Powell's contribution since they represent points which at first puzzled me:

At the top of Fig. 1, "yield strength at 35 percent set" should read "yield strength at 0.35 percent set."

At the bottom of Fig. 1, Poisson's ratio is stated to be 0.45. This value is questioned for the reason that it was determined from the very small difference between two diameters. An error of 0.0001 in. in these two diameters would bring Poisson's ratio down to 0.36. Poisson's ratio is less than 0.35 for nearly all metals and exceeds 0.40 only for such plastic materials as rubber, lead and paraffin.

The theory on which Mr. Powell sets up his trapezoid analysis is a bit difficult to understand. I suggest the first paragraph at the top of the middle column on page 291 be revised to read as follows: "The beam was then considered to be composed of two materials of dissimilar elasticity, one in tension and the other in compression, with the line of cleavage at the neutral axis. Assume that the true beam is replaced by one having the same modulus throughout and an effective area of trapezoidal shape having a depth equal to the depth of rectangular section of the true beam. If this is assumed to be true . . ."

In the illustrative problem, E_c from the compression test averaged 21,770,000. Its calculated value is 21,000,000, hence the error to be expected in calculating E_c from a known E_t is approximately 3½ percent, which is so small as fully to corroborate the theory.

Mr. Powell and PRODUCT ENGINEERING are both to be congratulated for making an important contribution of special value at this time due to the many unusual problems of design that come up in relation to defense activity.

To the Editor:

In reply to the comments of Mr. R. E. Bruckner on my article, "Bending Stresses in Materials Having Dissimilar Elastic Moduli," I am adding the following data and explanations:

There were fourteen tension bars pulled and four compression tests conducted by the writer in the B. W. S. testing Laboratory on cast manganese bronze specimens during the summer of 1940. The composition of the bronze by percentages was as follows: copper 58, zinc 39.2, iron 1.0, manganese 0.3, aluminum 0.5, tin 1.0, and lead 0.3.

An average E_t of all bars tested would be about 15,000,000 with a maximum disparity of approximately 1,500,000 above and below this value. Considerable larger variations were found for E_c ranging from 13,000,000 to 22,000,000 for the bar shown in Fig. 2.

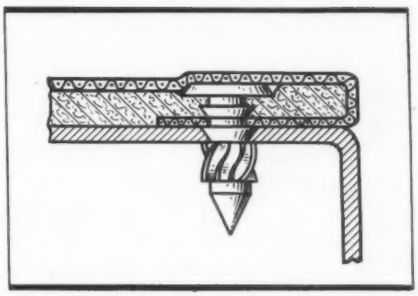
Concerning the decimal point omission in Fig. 1, Mr. Bruckner's statement is correct. It should read 0.35 percent set.

In reference to the subject of Poisson's ratio, I will say that the value shown is one of five taken on different specimens solely for the purpose of illustrating the differences in this characteristic for the various bars tested. Because of the possibility of a parallax error in reading fractions of one-tenthousandth of an inch with the micrometer used these values are at best only close approximations. Also since they were only apparent at comparatively high stresses (points well outside the proportional line), they are not significant for design purposes. Many engineering handbooks give a value of 0.333 for both brass and copper, so it would seem reasonable to assume the same for bronze. —WILLIAM I. POWELL

Drive Screws for Fabric

To the Editor:

Herewith is a sketch showing how our Type 21 hardened sheet metal drive screws are used to attach auto trim panel. This application is similar to Fig. 4 of your article "Fastening Methods



for Flexible Sheet Materials." In this fastening, it is only necessary to drill the proper size hole and drive in the screw with a hammer. —S. S. KAHN
Parker-Kalon Corp.

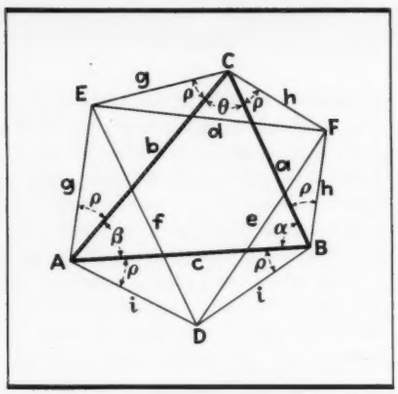
Interesting Property Of Triangles

To the Editor:

There is an interesting, and I think not generally known property of triangles that I have had occasion to study recently. If, based upon the three sides of any given triangle, isosceles triangles are constructed whose base angles are 30 deg., the apexes of the isosceles triangles will form an equilateral triangle. Thus in the diagram, triangle *ABC* is any given triangle, and triangle *DEF* by this construction is equilateral.

The analytical proof given below is quite rigourous but the rational physical explanation is also worth noting. If we assume 0 deg. in place of 30 deg. for the base angles, the triangle *DEF* becomes

similar to the given triangle *ABC* since it connects the midpoints of its sides; the proportional sides however are opposite. As the base angles are increased, the sides of triangle *DEF* grow



at a rate proportional to the size of the adjoining sides until 30 deg. is reached, when $d = e = f$.

Proof: from the cosine law:

$$d^2 = g^2 + h^2 - 2\,gh\cos(\theta + 2\rho)$$

But $g = \frac{b}{2} \times \frac{1}{\cos\rho}$; $\quad h = \frac{a}{2} \times \frac{1}{\cos\rho}$

$$d^2 = \frac{b^2}{4\cos^2\rho} + \frac{a^2}{4\cos^2\rho} - \frac{2\,ba}{4\cos^2\rho}(\cos\theta\cos 2\rho - \sin\theta\sin 2\rho)$$

$$= \frac{1}{4\cos^2\rho}\Big[b^2 + a^2 - 2\,ba\cos\theta\cos 2\rho + 2\,ba\sin\theta\sin 2\rho\Big]$$

$$= \frac{1}{4\cos^2\rho}\Big[ba\cos\theta + bc\cos\beta + ac\cos\alpha + ba\cos\theta - ba\cos\theta\cos 2\rho + 2\,ba\sin\theta\sin 2\rho\Big]$$

Since $b = a\cos\theta + c\cos\beta$;

$a = c\cos\alpha + b\cos\theta$

$b^2 = ba\cos\theta + bc\cos\beta$;

$a^2 = ac\cos\alpha + ba\cos\theta$

But when $\rho = \frac{\pi}{6}$,

$1/4\cos^2\rho = 1/3$

$-2\,ba\cos\theta\cos 2\rho = -ba\cos\theta$

$+2\,ba\sin\theta\sin 2\rho = 2\sqrt{3} \times$ *area ABC*

Then

$$d^2 = \frac{1}{3}\Big[ba\cos\theta + bc\cos\beta + ac\cos\alpha + 2\sqrt{3}\,ABC\Big]$$

Solving similarly for e^2 and f^2 the same is obtained, hence $d = e = f$.

I do not at present know of any engineering application for this theorem, but I feel that its novel character and the ingenious quality of the proof justify my calling it to your attention.

—Myron J. Drachman
New York, N. Y.

Substitute for Lucilite Insulation Material?

To the Editor:

We have been using in our instruments for some time a French insulating material known under the trade name of "Lucilite."

This plastic material is easy to machine and keeps its mechanical and electrical characteristics in oil at a temperature of 250 to 300 deg. F.

Up to now we have not been able to find a satisfactory substitute, and we would highly appreciate it if you could help us on this matter. —H. G. Doll
Schlumberger Well Surveying Corp.

[*Editor's Note*—Only thing we can think of, offhand, is a mica-filled plastic which keeps its electrical characteristics in water, is impervious to oil, and can be used up to 300 deg. C. as electrical insulation. There are probably others. How about it, readers?]

Error in Table Of "Shims for Bearings"

To the Editor:

I want to call your attention to a bit of confusion in Table II on page 313 of Product Engineering for June, in the article "Shims for Bearings."

In the column headed "Standard Thickness—in. Tolerance" a tolerance of +0.005/−0.000 applies to all three shim thicknesses of 0.062, 0.093 and 0.125 in. This is incorrectly shown in the table.

A tolerance of ±0.005 applies to the 0.187-in. shim thickness; this is correctly shown. —Albert B. Willi
Chief Engineer, Federal-Mogul Corp.

Number of Bolts a Factor In Total Load on Bolts

To the Editor:

The contribution entitled "Total Load on Bolts" by Walter M. Haessler on page 263 of May Product Engineering, was extremely interesting and Product Engineering is to be congratulated for its efforts to push this important phase of design through to a conclusion.

However, the analysis started off from one slight mistake in its premises, and therefore leads to a slightly incorrect final formula and fails to bring out one of the most interesting conclusions. In the original article, the "initial compression of the rubber block due to screwing up" is not βC_i, but βC_i *times the number of bolts.* However, the general method of analysis furnishes the key to the solution of this problem.

Using the same illustrations and the same symbols as appear on page 263, the corrected solution of this problem is presented as follows:

(1) Let α = stretch of each bolt in in. per lb. load Let β = vertical squeeze deflection of rubber block in in. per lb. load.

(2) Assume $2W = 0$. Then load on each bolt $= C$; vertical squeeze of block $= 2\,C\beta$; and stretch of each bolt $= C\alpha$.

(3) Assume $2C_i = 0$. Then load on each bolt $= W$; vertical squeeze of block $= 0$; and stretch of each bolt $= W\alpha$. Actually the gap between the block and cross bar will be $= W\alpha$.

(4) If bolts are stretched an amount αC_i to apply a load $2C_i$ to the block, and a load $2W$ is then added at the crossbar, each bolt will be subjected to a new load T always less than $W + C_i$ since the increased stretch of the bolts partially relieves the squeeze of the block.

(5) (a) Actual bolt stretch $= T\alpha$
(b) Bolt stretch at original load $2C_i$ on block $= \alpha C_i$
(c) Added stretch of bolts due to added load $2W = T\alpha - C\alpha = \alpha(T - C_i)$
(d) Reduction in reactive force of block $= \frac{\alpha(T - C_i)}{\beta}$
(e) Hence actual reactive force $2C$ of block after application of load

$$2W = 2C_i - \frac{\alpha\,(T - C_i)}{\beta}$$

(f) Hence actual total load

$$2T = 2W + 2C = 2W + 2C_i - \frac{\alpha\,(T - C_i)}{\beta}$$

hence for x bolts

$$T = \left(\frac{X\,\beta}{X\,\beta + \alpha}\right) W + C_i$$

With a large number of bolts, α becomes unimportant, and T closely approaches $W + C_i$ regardless of the values of β and α. This surprising conclusion is extremely interesting. It means that if a large number of bolts be used, instead of a few bolts as in the pneumatic jackhammer used for illustration by Mr. Haessler, increasing the bolt resiliency α will have practically no effect in reducing the bolt stress. In other words, for a large number of bolts, the bolt resiliency α must very greatly exceed the squeezed-block resiliency β to appreciably relieve the squeeze deflection of the block when any given external load xW is applied.

Conclusion (c) to the effect that the relative magnitude of α and β is of great importance, is true only for a small

number of bolts. Also, the observation that necking the bolts to increase α in relation to β will actually reduce the stress in the bolts, is perfectly true and is a phenomenon which has frequently occurred in the writer's experience. However, such occurrences are limited to cases in which the total number of bolts squeezing a given elastic assembly is relatively small as for example in a connecting-rod "big end" which usually employs only two or four bolts.

While the practice of increasing the bolt resilience to avoid breakage has been employed in all kinds of machinery for many years, it is extremely interesting to find that this type of reduction in bolt stress can be achieved only by substituting for a large number of small short or stiff bolts, a *few* long or resilient bolts. —ROBERT E. BRUCKNER
Manager of Machine Design
Kimble Glass Co.

Dished Heads Mixed Up

To the Editor:

I have seen my copy of the July number of PRODUCT ENGINEERING and am pleased to find that you have used the combined chart for dished head thickness. I do regret to advise, however, that there is an error in the chart on page 293. The section marked "Directions for Use" is incorrect and should read as follows:

1. Connect scale A_1 to B_1 for 75,000 lb. per sq. in. ultimate strength steel or similar alloy and read thickness on scale C.

2. Connect scale A_2 to B_2 for 55,000 lb. per sq. in. ultimate strength steel and read required thickness on scale C.

Reading it as published, the required thickness for stainless steel comes out greater than that required for 55,000 lb. per sq. in. steel. All readers should note this correction immediately.

—EDWARD L. MAGUIRE
Union, N. J.

Can You Work This One?

H. E. SMITH

This month's problem—

Royal Descendents

An elderly queen, her daughter, and little son, each weighing 195 lb., 105 lb., and 90 lb. respectively, were kept prisoners at the top of a high tower. The only communication with the ground below was a rope passing over a pulley, with a basket at each end. When one basket rested on the ground the other was opposite the window. Naturally, if one basket were more heavily loaded than the other, it would descend; but if the excess weight became more than 15 lb., the descent would be dangerously fast. From the position of the rope the captives could not check it with their hands. The only thing available to help them in the tower was a cannon-ball, weighing 75 lb. Notwithstanding, they contrived to escape safely. How?

Solution to July problem—

How Many Widgets?

When four companies, *A*, *B*, *C* and *D* contracted to make widgets, company *A* agreed to make half as many widgets as the sum made by the others, *B* contracted for one-third the sum of the others, and *C* made one-quarter the total made by *A*, *B*, and *D*. Since company *D* contracted for and delivered 325 widgets, it follows that company *A* made 500, *B* made 375, and *C* made 300 widgets. Total produced by all four was 1,500 widgets.

CASE HISTORIES IN PATENT LAW

H. A. TOULMIN, JR.

NO. 23

QUESTION: What interest does the Government have in any inventions made in filling of the war contract?

ANSWER: The Navy Department has a contract which it has entered into with many concerned which requires that concern to give the Navy a license under any invention which is necessary for the manufacture of the particular item in question. This contract also provides that any invention made in the course of carrying out the contract belongs to the Navy.

In some instances where special development work has to be done at Government expense, this is a legitimate and fair provision, but where the contractor pays for it at his own expense, and it is a development that is incidental to the filling of a wartime contract, the general rule is that he has a complete right to it, unless he contracts it away.

One of the difficulties that arises comes from the fact that in many contracts with the Army and Navy, the rights to such inventions are not provided for specifically. The first step is to define the extent to which the developments of the contractor are to become Government property. In this connection many controversies have arisen where Government employees, such as inspectors, engineers and others, have made inventions on Government time, with Government materials and at Government expense and in their direct line of work. If the Government does not put such inventions on the Secret List or on a list defining them as belonging to the Government, the contrary rule is that the invention belongs to the inventor subject to a non-exclusive license to the Government. The Government even goes so far as to not only pay the inventor's salary while he makes the invention, and pays for all the experimental work leading up to its creation, but even takes out the patent for him at Government expense. In a large number of instances such inventors have sold their interest to commercial concerns who in turn sell the same idea to the Government as contractors to the Government.

It is, therefore, important for a manufacturer who has Government employees in his plant to realize that he may provide them facilities and opportunities for invention of great importance to his company. The Government will get a non-exclusive license, but he may have to buy these inventions which, indirectly, he has paid for as a taxpayer. He has indirectly or directly provided the opportunity and facilities to such Government employees who may be in his plant to develop, invent and profit in a way that his own employees could not profit under the law. You will recall that the rule is, if one is especially hired to design, develop and invent, the invention belongs to his employer. If there is no contract and the invention is in the lines of his work and the invention is paid for by the employer, the employer in some cases owns the invention, in

others has a license, and in still others has a shop right depending upon circumstances.

In Solomons v. United States, 137 U. S. 342, one Clark (who was in the employ of the Government as Chief of the Bureau of Engraving and Printing) conceived the idea of a self-cancelling stamp and under his direction the employees of that bureau, using Government property, prepared a die to put into being Clark's conception. While the application for his patent was pending he assigned it to Solomons to whom he owed a debt. Solomons demanded compensation from the Government for the use of the invention. In these circumstances, Mr. Justice Brewer said:

Same as Any Other Employer

"The Government has no more power to appropriate a man's property invested in a patent than it has to take his property invested in real estate; nor does the mere fact that an inventor is at the time of his invention in the employ of the government transfer to it any title to, or interest in it. An employee, performing all the duties assigned to him in his department of service, may exercise his inventive faculties in any direction he chooses, with the assurance that whatever invention he may thus conceive and perfect is his individual property. There is no difference between the government and any other employer in this respect. But this general rule is subject to these limitations. If one is employed to devise or perfect an instrument, or a means for accomplishing a prescribed result, he cannot, after successfully accomplishing the work for which he was employed, plead title thereto as against his employer. That which he has been employed and paid to accomplish becomes, when accomplished, the property of his employer. Whatever rights as an individual he may have had in and to his inventive powers, and that which they are able to accomplish, he has sold in advance to his employer. So, also, when one is in the employ of another in a certain line of work, and devises an improved method or instrument for doing that work, and uses the property of his employer and the services of other employees to develop and put in practicable form his invention, and explicitly assents to the use by his employer of such invention, a jury, or a court trying the facts, is warranted in finding that he has so far recognized the obligations of service flowing from his employment and the benefits resulting from his use of the property, and the assistance of the coemployees, of his employer, as to have given to such employer an irrevocable license to use such invention." (P. 346).

In Houghton v. United States (C.C.A. 4), 23 F. (2d) 386, Houghton was employed as a trained chemist in the Public Health Service in the Treasury Department of the U. S. Government. He made an invention relating to fumigant gas for which he obtained a patent. As to this the Court said:

"But the case here presented is that of an employee who makes a discovery or invention while employed to conduct experiments for the purpose of making it. Houghton did not conceive the idea of combining an irritant gas with hydrocyanic acid gas, so as to produce a safe fumigant. That was the idea of Dr. Cumming, the Surgeon General, under whom he was working. He did not conceive the idea of using cyanogen chloride gas as the irritant with the deadly gas. That idea had been advanced in a German periodical, and experiments and studies along that line had previously been conducted at the direction of the Health Service. All that he did was to take the idea of the Surgeon General, upon which the Health Service had been experimenting, and conduct experiments under its direction, for the purpose of determining how best to produce and combine the gases so as to achieve the result which the Surgeon General had in mind. For this he was relieved of other work and sent to the Edgewood Arsenal to make the experiments. His regular salary was paid to him while he was thus engaged, and, when he deduced from the experiments the method to be followed in producing and combining the gases, he did merely that which he was being paid his salary to do. Under such circumstances, we think there can be no doubt that his invention is the property of his employer, the United States." (p. 388–389).

A Case of Shop Right Only

In United States v. Dubilier Condenser Corp., 298 U. S. 179, the Court had before it a situation in which scientists were employed by the United States in the Radio Section of the Bureau of Standards, but were assigned temporarily to another task than that called for by their regular employment, and while so temporarily engaged in research concerning use of radio in airplanes, they made discoveries concerning the use of alternating current in broadcast receiving sets—a subject not within their assignment and not being investigated by their Section. With the consent of their superior they perfected their inventions in the Bureau Laboratory and obtained patents thereon. In these circumstances the Court held:

"The bills aver that the inventions and patents are held in trust for the United States, and that the court should so declare. It is claimed that as the work of the Bureau, including all that Dunmore and Lowell did, was in the public interest, these public servants had dedicated the offspring of their brains to the public, and so held their patents in trust for the common weal represented here in a corporate capacity by the United States. The patentees, we are told, should surrender the patents for cancellation, and the respondent must also give up its rights under the patents.

"The trust cannot be express. Every fact in the case negatives the existence of one. Nor can it arise ex maleficio. The employees' conduct was not fraudulent in any respect. They promptly disclosed their inventions. Their superiors encouraged them to proceed in perfecting and applying their discoveries. Their note books and reports disclosed the work they were doing, and there is not a syllable to suggest their use of time or material was clandestine or improper. No word was spoken regarding any claim or title by the Government until after applications for patents were filed. And, as we have seen, no such trust has been spelled out of the relation of master and servant, even in the cases where the employee has perfected his invention by the use of his employer's time and materials. The cases recognizing the doctrine of shop rights may be said to fix a trust upon the employee in favor of his master as respects the use of the invention by the latter, but they do not affect the title to the patent and he exclusive rights conferred by it against the public" (pp. 196–197).

In Standard Parts Co. v. Peck, 264 U. S. 52, it was held that one who is employed and paid by another to develop a process and machinery for manufacturing a specified product, and who obtains a patent for an invention made by him in the course of the employment, holds the patent for his employer. In the language of Mr. Justice McKenna:

"By the contract Peck engaged to 'devote his time to the development of a process and machinery' and was to receive therefor a stated compensation. Whose property was the 'process and machinery' to be when developed? The answer would seem to be inevitable and resistless of him who engaged the services and paid for them, they being his inducement and compensation, they not being for temporary use but perpetual use, a provision for a business, a facility in it and an asset of it, therefore, contributing to it whether retained or sold. . . ." (pp. 59–69).

Thus it is necessary to have a clear understanding as to the ownership of inventions to prevent serious disputes.

News and Summaries

Army Will Have Trucks, At Least

Motorization of Army called for two big design jobs: development of all-wheel drives and interchangeability of parts

WHEELED WAR EQUIPMENT for United States defense is now coming off the motor industry's assembly lines at the rate of 20,000 per month—production unmatched by any other country in the world. By the end of 1941 the Army will have 237,912 motor vehicles—one for each five of the present 1,418,000 men. One-third of these men will be engaged in the transportation of the other two-thirds.

The Army has two kinds of motor vehicles. One is "mechanized" or armored division equipment, which consists mostly of tanks. Soldiers ride and fight in these machines. The other kind is "motorized" equipment, whose function is simply hauling. Men ride to battle in it, but they don't fight in it.

To classify still further, there are two kinds of motorization: one is "administrative" which means mostly passenger automobiles and few trucks. These are almost standard commercial vehicles, ordered with olive drab paint. The other kind is "tactical" vehicles—those which accompany the Army in the field. Tactical vehicles are the big volume and the big problem because they are not commercially standard. There are five sizes of tactical trucks: ½-ton; 1½-ton; 2½-ton; 4-ton; and 6-ton. The new ¼-ton "jeep" is the sixth.

For all of these the Army has adopted the 4-wheel drive. They feel that four wheels give more than double the traction of two. Four-wheel steering has been abandoned; such a truck can't get away from a curb. Army had to develop all-wheel drives because commerce doesn't use them. Six-wheel drive, for instance, is complicated. The engine drives through a conventional transmission into a "transfer case" just back of the engine. Out of the transfer case goes a shaft to the front axle differential, which is off center. Back from the same case goes another shaft into both of the rear axles. In some designs, two shafts run separately to the rear axles. Because there is no differential in the transfer case, all three axles must turn at same speed. When the truck is not loaded, the front wheel tires are flattened down to a smaller diameter than the rear wheels. Result is a "scrubbing" action on front tires. To prevent this, the front axle is automatically de-clutched on good roads.

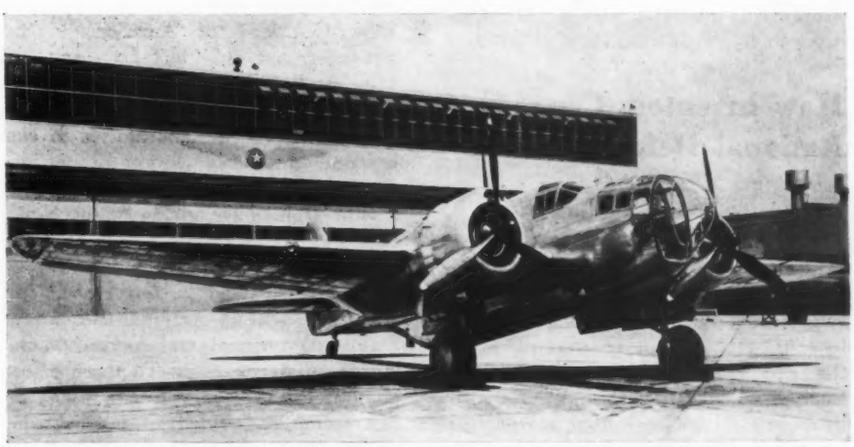
Next important development job was standardization and interchangeability of parts. A lesson was learned on this in the World War, when 216 makes of vehicles were used, including many foreign ones. This number has been reduced to 16, which are variations of the six basic types.

Manufacturers have worked out a plan for interchangeability. This has been accomplished in conference over the last 10 months with the Army and the Society of Automotive Engineers. Standardization is applied also to gasoline, 3 types of which are now used instead of 4. There is hope that this can be cut to just one, probably 80 octane, and one diesel fuel. Engine oil types have been cut from 8 to 3; transmission oil from 4 to 2; grease from 5 to 3. Repair equipment includes 22 different types of tool sets. The Quartermaster figures that $100,000,000 worth of vehicles will require $18,000,000 worth of spare parts.

Ford, American Bantam, and Willys-Overland are dominant builders of the ¼-ton 4x4 (first figure is number of wheels; last one, the number it drives on). Fargo is top on ½-ton 4x4; on 1½-ton 4x4 it's Chevrolet; Yellow Truck works on 2½-ton 6x6; Federal Truck makes variations in the 4–5-ton trucks and trailers; 4-ton 6x6 goes to Diamond T; 5–6-ton 4x4's are built by Mack International and Autocar; 6-ton 6x6's are contracted with Mack and Corbett.

Diesel Cylinder Liners Now Induction Hardened

LONGER-WEARING sleeve liners for diesel engines are being produced at Caterpillar Tractor Company by induction hardening. An induction heat "head" that is drawn up through the liner heats only the inner surface zone to required temperature. This is followed immediately by a controlled water quench, giving a hardness of 52 to 55, Rockwell C, to a depth of about 0.070



We'll hear more of this in the war news, Glenn L. Martin Company hints as they release first details of this Martin 187 ("Baltimore") medium bomber. Built for Royal Air Force, it is said to be fastest of its class, capable of outperforming many late types of pursuits, and equally suitable for bombing or long-range reconnaissance. Mid-wing, deep-waisted design is powered with two 1,600-hp. Wright engines; carries crew of four. All-plastic nose gives bombardier wide visibility; other new uses for plastics are intimated. Fifteen acres of floor space will be devoted to assembly of this ship alone.

Chrysalis stage of a nickel-clad steel tank car looks like this, as a 6-in. layer of spun glass wool insulation is applied to the first of American Car and Foundry's new all-welded cars. Designed for products such as phenol, solvents, alkalies, syrups, the lower half of the tank is jacketed with steam pipes to permit heating of materials loaded and unloaded in hot, fluid state. Seams are "Union-Melt" welded on outside, hand-welded with nickel electrodes on inside. Each 10,000-gal. tank is over 32 ft. long, 83 in. dia., and is mounted on standard truck with special anchor welded to tank. No bolts go through shell. Wooden cradles support the ends. Welded construction eliminates loosened rivets caused by mechanical vibration or expansion and contraction from hot ladings. Tank is annealed after welding. Jacket over outside of insulation is welded steel. All fittings are either nickel lined or pure nickel.

in. The surface is then tempered to slightly lower hardness. While the bores are extremely hard, the sleeves are not brittle.

After tempering, the bores are honed, and the outside diameter is finish-turned. Liners from 10 to 15 in. long with bores from 3¾ in. to 5¾ in. dia. are now in production on machines developed by Budd Induction Heating.

How Inventors Can Aid National Defense

To aid inventors interested in communicating with the Council, the Department of Commerce has published an informative bulletin, "How Inventors Can Aid National Defense," which describes the purpose, technical committees of, and procedure suggested for the submission of inventions to the Council. Instructive literature is also listed in the booklet, so that prospective inventors may gain a familiarity with the military requirements surrounding the use of their proposed devices or inventions.

Approximately 30,000 communications, of which about 16,000 contained inventions or inventive ideas, were received by the Council during its first six months of operation.

Aluminum Research Aimed At Aircraft Problems

WITH GOVERNMENT ARSENALS, even, under orders to reduce aluminum requirements in ordnance, aluminum producers today are concentrating nearly all their efforts on aircraft production. Aluminum Company of America, biggest producer, not only has been required to expand production facilities, but also is redirecting the whole broad program of their Research Laboratories to concentrate on finding answers to questions coming from the aircraft industry.

Into prominence in the research picture has come a new group of collaborators: Army, Navy, Langley Field, Wright Field, Army Ordnance, and agencies such as National Bureau of Standards and National Advisory Committee on Aeronautics. To these offices go the results of all investigations on the mechanical properties and behavior of aluminum and magnesium.

Extensive tests are being carried out on fabricating techniques, such as on heat-treating, used in the aircraft plants. Development of casting techniques for magnesium alloys is aiding production of aircraft engines. Alloy development work gives consideration not only to improved physical properties, but also gives consideration to production requirements and the conservation of strategic materials. Modification of existing alloys is solving some of these problems.

Aluminum production has climbed by leaps and bounds since the realization of the impending shortage. Alcoa reports the trend of their production, in millions of pounds, as follows:

1938	287
1939	327
1940	412
July, 1941	600 per year approx.
July, 1942	720 per year approx.

Most of this increased capacity is in castings and forgings. Alcoa released to PRODUCT ENGINEERING the following percentage increases in capacity, by form, since September 1939:

	June 1941	December 1941	July 1942
Castings	130	210	
Forgings	114	163	
Sheet, Plate	43	56	103
Extrusions	0	138	

Emergency Standards To Help Speed Up Inspection

TWO NEW EMERGENCY defense standards which will help the manufacturer to spot trouble before that trouble becomes bad enough to cause rejections, have been developed by the American Standards Association upon the request of the War Department.

Cardinal feature of the method is a "Control Chart" on which a running record of the results of inspection of the product are charted. Two horizontal lines, called "control limits," are drawn on the chart. When the plotted points fall between these limits, the production process is "under control."

Adoption of this control, it is hoped, will lead to acceptance of a product by the purchaser based upon the manufacturer's evidence of control, rather than upon the purchaser's own sampling. The Bell Telephone system and other companies are already applying these methods successfully.

Do You Know That—

ELECTRICALLY CONDUCTIVE RUBBER is used in the tail wheels of aircraft to bleed off static charges, accumulated in flight, as soon as the plane touches the ground. (52)

VALVE SPRINGS for automotive engines are now all made from wire which has been given a shotblast treatment. The process cold works the surface of the wire, increasing its endurance limit by 16 percent. (53)

ENGINEERING IN WASHINGTON

McGRAW-HILL WASHINGTON BUREAU, *PAUL WOOTON, CHIEF*

British "radiolocators" for anti-aircraft defense, now in mass production, are the technical talk of the town. One fine day His Majesty's Embassy here called the press to sit in splendor on its terrace and hear that Britain wants a couple of thousand American volunteer technicians to service the locators, being scattered throughout the United Kingdom. Air Commodore George C. Pirie let out only the skimpy facts that the devices are in the class of heavy machinery, but that they probably can be carried aboard planes.

Diligent inquiry revealed that the locator works on the microwave band of the radio spectrum. Radio emanations of this class are quasi-optical, and they can be focused. The transmitter scouts the air space where enemy aircraft are suspected. When it catches one, or more, the wave echoes back. The orientation of the transmitter gives the line on which the plane is located. Triangulation on a reading from a second locator gives the exact position. Repeated "readings" give the course of the plane or planes. Then, when the enemy comes close enough, the locator enables AA guns to take aim at individual planes without seeing them.

This is the night bombing defense which the British said they were working on last winter. They no longer hope, as they did then, that it will stop night raiding, but they are sure of drastic curtailment. The locator will aid in attack too, because it can follow both attackers and the enemy, and inform British pilots when they are near hostile craft.

The British said that the locator has been turned over to the United States Army. They admitted that Germany has locator devices but which are not, in their opinion, nearly so effective.

Three automatic cannon are now in production for the various branches of the Army. An automatic cannon differs from a machine gun in that it fires explosive shells rather than mere slugs, and is of larger bore. The latest automatic cannon, or "shell gun," is a 40-mm. automatic anti-aircraft weapon, whose carriage and operation are so designed that it can be put in action in a few minutes. Its purpose is to attack low-flying or "hedge-hopping" army planes. Heretofore, the hedge-hoppers have got away with murder because nothing but rifles and small machine guns could get a crack at them. The regular AA guns can't be brought to bear quickly enough, and some of them have too much elevation except for high targets. The new 40-mm. gun fires a shell weighing 2.2 lb. One hit from an explosive shell usually puts a plane out of action, whereas it might fly away with hundreds of bullet holes. The other two automatic cannon referred to above are the 37-mm. and the 20-mm. Both of these are adapted to air and anti-air use, and to tank and anti-tank. We have two sizes of machine guns: .30-cal. and .50-cal. The Tommy gun, a sort of machine pistol, is .45-cal.

What this country needs is an alchemist who could turn the Fort Knox gold into aluminum. The states of Washington and Utah have been using aluminum hickies as sales tax money and now they have to change to some other metal—get off the aluminum standard, as it were. The National Academy of Sciences has advised OPM to call for extensive substitution of silver for tin in soldering. Such action, the NAS committee said, plus reductions already being affected by can manufacturers, would cut consumption of tin about 25 percent.

Artificial fog, in case you want to make some after reading how the Nazis laid it down on Crete, is probably titanium tetrachloride, the same stuff the Navy uses for smoke screens and which sky-writers use for chalk. We inquired around and found nobody here who had heard of the stuff being used before in land warfare. Everybody admitted, though, that it would be terrifying to retreating and confused men, or even to advancing men. Chemists said it is probably harmless to lung and mouth tissue. You'll probably hear more about this newest way of making life miserable.

Torpedo boat carriers are being studied by the Navy, upon request of the House Naval Affairs Committee, even though Admiral Harold Stark reported unfavorably on a previous survey. Admiral Stark said that in 1921 the Germans converted two ships to carry torpedo boats, which were quite small then, and that after two years the project was abandoned. The Admiral adds that these so-called "suicide" boats are good only as weapons of opportunity; that in heavy weather (at sea) they are ineffectual. The new designs are big, heavy (36 to 40 tons), and fragile, and therefore difficult to handle with hoists. Due to their size, only a few could be placed on a carrier. The possibility of launching them from a ramp was studied and found impractical.

Two tugs and a little ship are newly designed by the Maritime Commission. One of the tugs has a coal-burning boiler and a 1,000-hp. compound steam reciprocating engine. It is 109 ft. long. The other design provides Diesel electric propulsion with one or two generators driving through a single screw. It is 105 ft. long. The small cargo ship, or "coaster," is 258 ft. 9 in. long by 42 ft. 1 in. beam; draft 17 ft. 11 in.; 2,800 tons deadweight; speed 10½ knots. It is coal-burning with reciprocating steam engine and single screw, and can pass through the Welland Canal between Lakes Ontario and Erie.

The Army is looking for a tank destroyer. So far, there is nothing that can fight a tank but another tank. Some sort of light, agile vehicle, that can run around tanks and pour shells into them, is needed. Consideration is being given to mounting 37-mm. shell guns on the little "jeep" cars and letting them try it. But losses would be high, and the 37-mm. shell cannot be depended upon to penetrate the new, heavy tank armor. If the rule which holds that every new weapon soon brings a defense against it is true, there'll be a tank destroyer, soon or late.

Loss of the submarine O-9 is under investigation by the Navy. The sub was built in 1918, and the re-commissioning of the O-9 and others like it has been criticized. Meanwhile, testimony on the subject reveals that present undersea boats are built to withstand a pressure of 300-ft. depth. In 1918 the limit was 200 ft. The O-9 apparently was crushed by water pressure. She was found 440 ft. down, but it was not known whether she collapsed at a lesser depth. Incidentally, the divers who went down to look at her established a world record.

New Materials and Parts

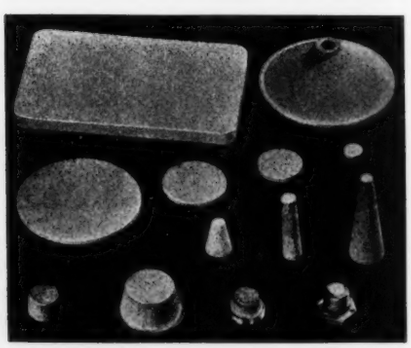
Electric Stop Watch

Known as the "Time-It" minute model, this new electric stop watch is run by a synchronous electric motor which operates a direct reading indicating counter. Accuracy is covered by the cycle constancy of 115-volt a.c. supply. The device integrates to 1,000 min., reading in full minutes and hundredths of a minute. It can be reset to zero from any reading, or successive

readings can be totalled. Applications include laboratory procedures, time study operations, timing of long telephone calls, motor dynamometer tests, etc. The Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.

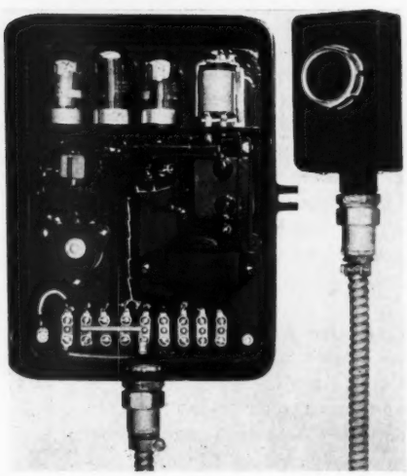
Porous Metal

"Porex" has two principal functions: to remove foreign materials from fluids such as oil, and to alter the characteristics of gases by diffusion, reducing pressures and controlling flow rates. Porex is manufactured from powdered metal subjected to a series of processing operations. Applications for the Porex metals are found in almost any appliance or piece of industrial equipment



involving the flow of gases or liquids. Suggested applications are in pumps, refrigerators, fuel lines, lubricating systems, oil burners, evaporators, absorbers, paint sprayers, premixed gas burners and other devices. The new filter and diffusing material, for example, is used to prevent clogging of orifices in diesel injector nozzles or oil burner nozzles. Advantages of Porex are in physical characteristics, structure, porosity, strength and ductility, which can be varied within certain limits to suit specific applications. Available in disks, sheets, cylinders and truncated cones. Moraine Products Div., General Motors Corp., Dayton, Ohio.

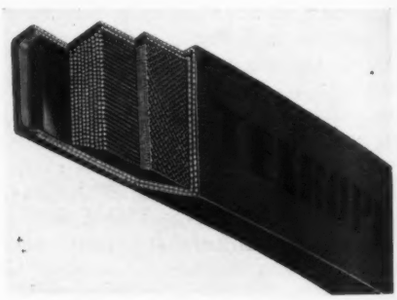
Photoelectric Inspection and Registration Control



A simplified system for accurately controlling or inspecting cutting and printing operations on materials such as cellophane, paper, cloth, tin, metal-foil, is offered by this new photoelectric inspection and registration control Type A80. It can also be used for detecting the presence or absence of labels on cans, the proper location of labels on goods, and similar applications. All amplifying tubes are standard vacuum type. Type A80 control observes registration marks from penetration of light through transparent and translucent materials as well as reflection from opaque materials. An impulse of as short a duration as 0.001 sec. will be detected by the control and converted into a controlling operation. Control relay remains in operation until the controlled circuit has completed its function, at which time the unit is reset automatically. Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.

New V-Belt Structure

The cords in the new Super 7 belts are smaller, permitting more cords per belt with a resulting greater strength and less stretch. Each cord is individually imbedded in heat dissipating rubber to reduce internal belt degeneration. These belts are made in matched sets to assure uniform, smooth running, highly efficient drives. Live rubber bottom cushion absorbs the ceaseless impacts of operation. Central cord portion transmits power at the effective pitch diameter. The bias-cut fabric prevents "dishing" and assures transverse stability. The two-ply rubber-impregnated fabric cover prevents destructive agents from reaching the vital belt elements, resulting in a high grip coefficient between belt and sheave walls. All Texrope V-belts are now of this design, based on the Vogt formula and abundant field experience. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

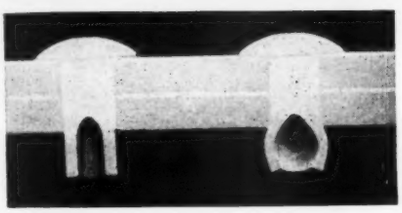


Pressure Adhesive Tape

Pressure-sensitive adhesive tape with a 100 percent wool felt backing is manufactured in four different widths; ¼ in., ½ in., 1 in., and 2 in., with a crinoline interliner. The backing itself in finished form varies in thickness from 0.050 in. to 0.055 in. White is the standard color, but it will also be available in other colors on orders large enough to justify extra-standard production. Industrial Tape Corp., New Brunswick, N. J.

Explosive Rivets

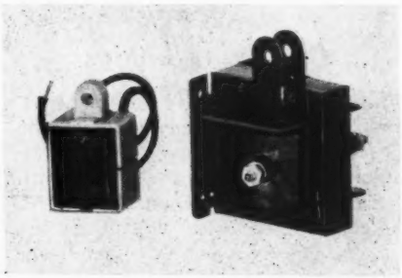
Explosive rivets of a new type, with a high explosive secreted in a cavity at the end of the shank, are "set" by applying heat to the rivet head with an electric gun which detonates the charge. The explosion expands the charged end of the shank, thus forming a "blind" head. The whole operation is performed with greater ease and speed than is



possible by mechanical means now in use in aircraft factories. From 15 to 20 of these blind fasteners per minute can be set by one workman, once they are inserted in the holes. The rivets themselves weigh only about one-fourth as much as generally used blind fasteners. Riveting gun or iron weighs less than 5 lb. So finely has the explosive charge been controlled that the expansion it effects can be held within limits of 0.020 in. Rivets are now available in aluminum alloy in varying sizes and diameters and with modified brazier heads or countersunk type heads. They are installed in the age-hardened condition and do not require refrigeration after heat-treatment. These rivets develop shear and tension values approximately the equivalent of driven rivets, and are anodized to prevent corrosion. E. I. du Pont de Nemours & Co., Wilmington, Del.

Solenoids

New line of solenoids is available in a wide range of sizes and strokes. Small sizes and short stroke solenoids can be used for animated advertising displays, coin-operated or pin game devices, electric gongs, etc. Large sizes are used on machine tools, feed mechanisms, canning and bottling machinery, textile machines, damper control, electrically-operated valves, ratchet mechanisms, brakes, clutch levers. Automatic operation can be effected by means of limit switches, mercury contacts, pressure switches, or pushbuttons. Made for continuous or intermittent duty and voltages up to 550 volts, 25 or 50/60 cycles, and up to 550 volts d.c. for intermittent duty only. Shading coils are correctly proportioned for quiet operation; center pole and plunger faces are carefully ground. Jefferson Electric Co., Bellwood, Ill.

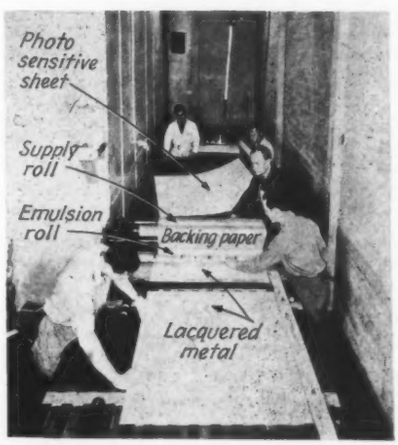


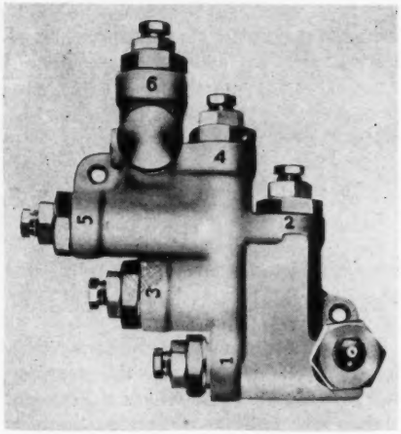
Circuit Interrupter

This sheet steel, dust-resisting circuit interrupter is designed to replace non-automatic disconnecting devices used in industrial plants, central stations, and locations where inclosed, unfused safety switches might be applied. High interrupting capacity and reduced mounting space are featured in the new non-automatic "De-ion" circuit interrupter. These two or three-pole interrupters known as NEMA Type 1A, have 50 to 600 amp. ratings on 250 to 600 volts a.c. and 125/250 and 250 volts d.c. lines. Rust and corrosion-resisting metals are used in all units, and all main contacts are of non-welding silver or special silver composition. De-ion arc quenchers are used to reduce contact burning and preserve the contacts. Safety features include a cover interlock which prevents closing of contacts when cover is open. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Matte Transfer Film For Sensitizing Metal Plates

Photographic material for sensitizing metal plates for use in the templet process that shortens the time between engineering and test flights in the aircraft industry is now available to all industries. (P.E. Aug. 1940, p. 377.) With the use of Matte Transfer Film, engineering drawings can be printed either by contact or by projection on these photosensitive metal sheets. The processed plates bearing the photographic image are then cut out directly and used as patterns or templets. Cutting is by saw or mechanical shears. The photosensitized metal sheets can also be filed, drilled and punched. The most simple and effective method for producing sheets of photosensitized metal consists of laminating Matte Transfer Film to lacquered metal sheets. The film consists of a sensitive emulsion coated on a thin film support, the latter backed by a paper base. The sensitized strip is transferred from the supporting paper base to the lacquered metal plate. The film has a matte surface, so that it will take a pencil line in case changes or additional developments on the processed photographic image are desired. Width of Matte Transfer Film is limited to 34½ in. Experts of the Kodak Co. are available to anyone interested in designing and installing the equipment, similar to that of the Lockheed Aircraft Corp. illustrated necessary to produce these photo templets. Eastman Kodak Co., Rochester, N. Y.



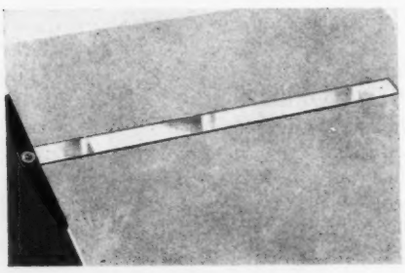


Lubricating System

Centralized to permit high-pressure grease lubrication to any number of bearings on a given piece of industrial equipment, this new progressive lubricating system delivers a predetermined quantity of lubricant to from 3 to 20 bearings. When the job is completed, a visible indicator signals the operator. On equipment that involves a large number of bearings, Alemite progressive lubricating systems can be employed in relays. Any type of manually or power operated high-pressure grease gun can be used with the systems. One system or a relay can be installed with ease on the most intricate piece of machinery. Alemite Div., Stewart-Warner Corp., 1826 Diversey Parkway, Chicago, Ill.

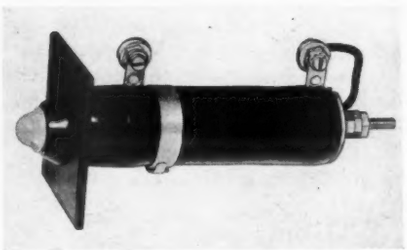
Plastic T-Square

Particularly adaptable where it is desirable to view the entire drawing without moving the T-square, the head of the Escolite T-square is made of black laminated bakelite composition, $\frac{5}{16}$ in. thick, and the blade is of a crystal-clear transparent plastic, 0.090 in. thick. Eight cone-shaped pins are accurately and securely set into the head. These pins engage corresponding openings in the blade, eliminating wobble and automatically taking up play. No paper rabbet is necessary because the head is held $\frac{1}{16}$ in. away from blade. A special die-casting and single screw holds the entire assembly together. The plastic used in the T-square will not warp, bolt, chip, crack or split. There is no finish to wear off, chip or peel. A swivel head can be added at any time. Engineering Sales Co., Sheboygan, Wis.



Indicating Lamps

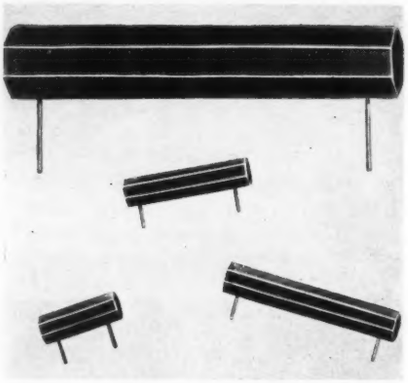
These rugged lamps for visual or pilot light indication on switchboards, switchgear, panels and controls are simple in construction and require little panel space for mounting. Special material in the color cap allows less lamp voltage with equal brilliance and corresponding longer lamp life consuming only approximately 4 watts. Color caps are threaded and easily removed and replaced from the front of



the board. Receptacle is of insulating material and mounts from the front of the panel through a $\frac{3}{4}$-in. hole. Resistor slips over the receptacle, taking little space. Strong, resilient, metal contact clips firmly hold the lamp bulb in position. Assembly mounts on any thickness of panel up to 2 in., without counterboring, and projects less than 5 in. from the face surface of the panel. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Negative Temperature Coefficient Resistors

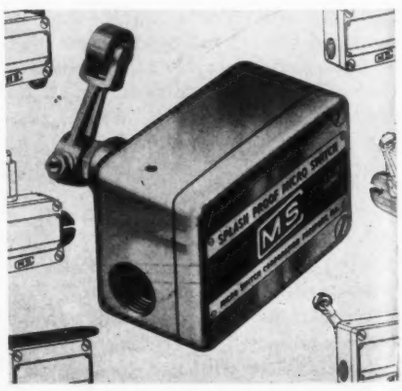
Resistor material in this new line of negative temperature coefficient resistors is a hard, black, non-metallic substance, the chief characteristic of which is a decrease in electrical resistance with an increase in temperature. This property makes the material useful where it is desired to reduce or eliminate initial current surges, to secure a time delay or gradual building up of the current through a piece of equipment, to provide temperature compensation in apparatus or equipment which exhibit rising resistance with increase in temperature, and for other applications where a negative temperature coefficient is required. The temperature of a resistor made of this material can be changed either externally by a change in ambient temperature, or



internally by heat developed by passage of current through the resistor, or by a combination of both. Change of resistance with temperature change occurs in the region of ordinary temperatures: namely, 0 to 150 deg. C. Connections are molded in for permanent electrical contact. Available in a wide range of resistance values, and a wide variety of sizes and shapes. Keystone Carbon Co., 1935 State St., St. Marys, Pa.

Splash-Proof Micro Switch

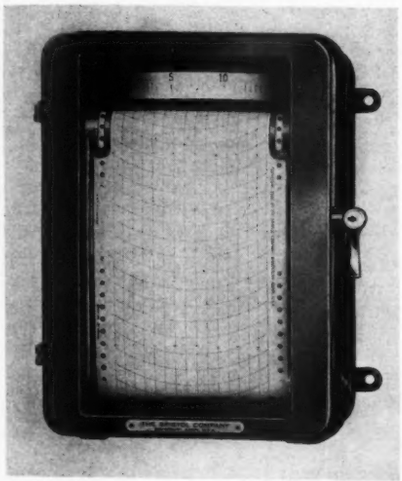
A precision switch housed in a splash-proof, malleable case which can be conveniently mounted from any one of four sides for use as an interlock, limit, or pushbutton switch, has been announced. The variety of mounting positions is a feature of the switch. There are two tapped holes for No. 10-32 screws on each of the four sides. This makes it possible to mount the switch directly to a machine frame from practically any position, whether the switch has the roller arm, cross-roller arm, or push-rod plunger type of actuation. If lug or foot mounting is desired, $\frac{3}{16}$-in. thick steel mounting plates can be furnished. Switching element is a standard Micro Switch. Both types of roller arm are of aluminum, adjustable through 360 deg. with the roller of a non-sparking material of high concentricity. Overtravel on this switch is 90 deg. The plunger



type of actuator has a bullet-nose push-rod of case hardened steel which moves in a long cadmium plated hexagonal bushing. A removable cover provides access to terminals. Switch can easily be removed for inspection. Micro Switch Corp., Freeport, Ill.

Strip-Chart Recorders

Many changes have been made in the construction of these new strip-chart recorders, including the case design, chart drive, measuring elements, and writing mechanism. They are available for recording on a six-inch strip chart, d.c. volts and millivolts, d.c. amp. and milliamp., pressure, liquid level, flow, temperature, motion, and for remote recording. The Bristol Co., Waterbury, Conn.



Method for Marking Enameled Metals

Consisting of a steel die application to the coated metal under electrically controlled conditions, this new method of marking enameled metals without engraving reduces the marking time. Binocular parts, enameled tubes, camera parts, instrument cases and a wide variety of enameled metal products can be trade-marked, numbered, or otherwise marked by this new process. A special machine to simplify the procedure has been developed. The Acromark Corp., 251-257 No. Broad St., Elizabeth, N. J.

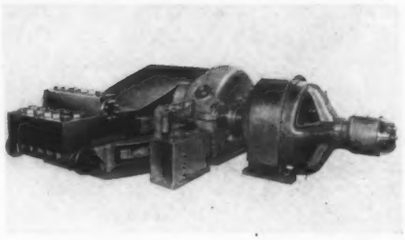
Industrial Multi-Breaker

For use on 230-volt a.c. systems, this new industrial Multi-Breaker is available in 2- and 3-pole forms in capacities from 15 to 100 amp. The inclosure is dust-resisting with a felt gasket between box and cover. Operating mechanism is mounted on the cover of the box so that when the cover is removed the entire interior around the breaker is left free for wiring. A switch make-and-break mechanism is also incorporated on the cover assembly. Indication of a tripped condition of the breaker is by the white target signal. Front operation of the breaker permits close ganging of units, and there is provision for padlocking in either "on" or "off" positions. The breaker units used in industrial Multi-

Breakers are all common trip so that an overload on any pole will cause all poles to trip simultaneously. This eliminates the possibility of the breaker causing the single-phasing of polyphase circuits. A thermal element affords a time lag on momentary overloads while a magnetic trip feature causes instantaneous tripping on heavy short circuits. Square D Co., 6060 Rivard St., Detroit, Mich.

High-Pressure Pumps

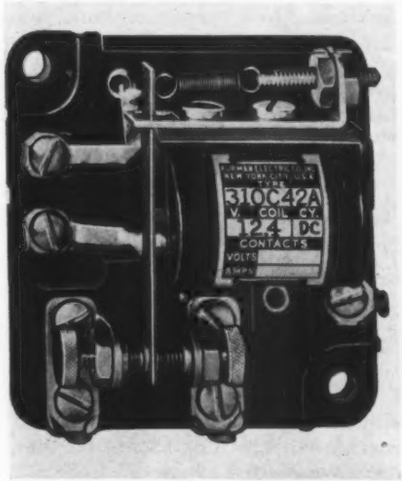
Designed to handle comparatively large volumes of water for operation of hydraulic presses, these Horizontal Triplex pumps have three pistons—an arrangement which provides a 60-deg. overlap in discharge impulses and tends to smooth out pump pulsations. Designed primarily for pressure in excess of 1,000 lb. per sq.in., these Horizontal Triplex pumps are built in 12, 15 and 18-in. stroke lengths. They are designed for direct coupling to 125, 250 and 500 hp. motors, respectively. The 12-in. stroke pump discharge ranges from 23 g.p.m. at 7,500 lb. per sq.in., to 160 g.p.m. at 1,000 lb. per sq.in.; that of the 18-in. stroke unit from 88 g.p.m. at 7,500 lb. per sq.in., to 685 g.p.m. at 1,000 lb. per sq.in. Other capacities and pressures



are available. The pump frame is a one-piece semi-steel casting which carries the bearings for the rotating parts. The gear case, containing double helical single reduction gears, is cast integrally with the frame. All rotating elements are mounted in roller bearings, except crank ends of connecting rods which use steel-backed babbitt bearings. Valves are of bronze; seats are of stainless steel. The cylinder block is one-piece steel forging. Baldwin-Southwark Div., The Baldwin Locomotive Works, Philadelphia, Pa.

Sensitive Power Relay

Latest development in sensitive relays is the Model BK25 sensitive power relay, which has voltmeter accuracy in the range from —24 to +99 deg. C. Molded base, of Navy-approved material, and silver contacts contribute to its claimed perfect performance despite vibration or temperature changes. Operates on 0.0018 watts. Kurman Electric Co., 241 Lafayette St., New York, N. Y.



Baking Enamel

A finish which is suggested as a replacement for chromium plating and baking enamels rendered impractical or unavailable due to defense demands, claimed to have remarkable draining characteristics, unusual gloss, superior color retention, and will not scratch

easily. One coat is said to cover with a smooth, wax-like finish that will stand extreme wear and weather abuse. It is said to be free of the tendency to thicken, "liver" or disintegrate in the dipping tank. It is thinned with oleum spirits, and will bake out in 15 min. at 300 deg. F. Available in all colors, including white. P. D. George Co., St. Louis, Mo.

Machine Tool Enamel

Faster synthetic enamel for machine tool castings, known as Kem Machine Tool Enamel, is said to cut many hours and even days from the finishing time formerly required on large tools,

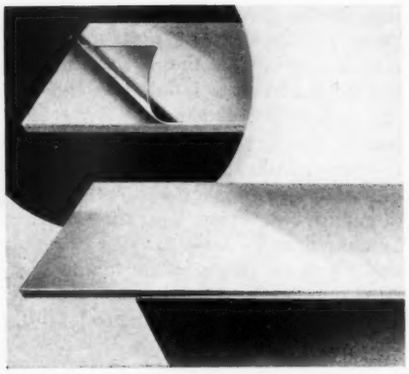
and is said to give far greater resistance to cutting compounds. The new Kem finishes can be applied in 5¾ to 8½ hr., four coats, thus permitting work to be shipped the same day it is finished and assembled. A typical drying schedule follows:

Spray or brush coat Zinc Chromate Primer	15	to 30	min.
Machine Filler	4	to 5	hr.
Kem Sealer Gray....	15	to 30	min.
Kem Machine Tool Gray	15	to 30	min.
Dry and crated	1	to 2	hr.
Total	5¾	to 8½	hr.

Typical machine tool casting finished with Kem machine tool enamel is shown. Sherwin-Williams Co., Cleveland, Ohio.

Wide Laminated Shims

Laminated shim stock is now in production with a 7-in. usable width, permitting the manufacture of larger jointless shims, and affording greater convenience to purchasers who cut their own shims. Lengths are available up to 36 in. The new sheets are available in overall thickness from 0.006 to 0.125



in. All of these thicknesses can be obtained in all-laminated sheets with a choice of 0.002 or 0.003-in. thick laminations, or various thicknesses can be had partly laminated and partly solid. Laminated Shim Co., Inc., Union St., Glenbrook, Conn.

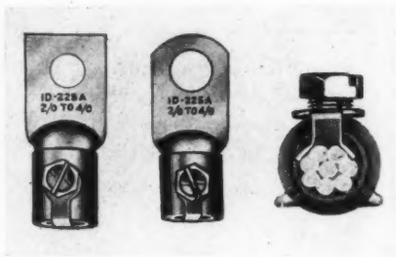
Sheet Metal Fastener

Designed especially for fastening aircraft handhole covers, engine cowling, access plates, and similar parts, this new Dot cowl fastener can be applied to any flat or curved sheet metal surfaces. The fastener is self-aligning, and can readily be engaged or disengaged. When the stud is turned in a counterclockwise direction, the pin working on the under surface side of the cam acts as an ejector. In other words, the stud pin may pass under the spring during detachment to force the plate apart quickly. This fastener is adapted to

variations of at least $\frac{1}{32}$ in. in thickness without change of location of pin. It has approximately $\frac{1}{16}$ in. pick up or lift. The ends of the spring are rolled up to eliminate the possibility of its digging into the material in being assembled. Spring is hardened and cadmium plated for rust, corrosion and wear resistance. Rivets for standard $\frac{1}{8}$-in. hole for attaching spring can be supplied in cold rolled steel, cadmium plated, or aluminum if required. Studs are of case-hardened steel with wear-resisting pin, cadmium plated. The stud is assembled by the simple spring ring which can be attached or detached easily. United-Carr Fastener Corp., 31 Ames St., Cambridge, Mass.

Setscrew Type Lug

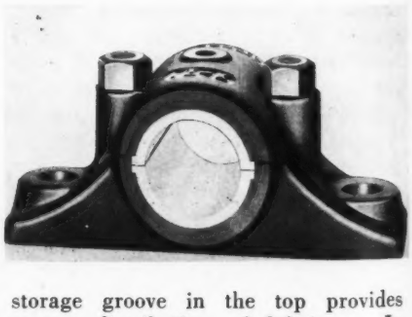
A new solderless "Screw-Tite" lug of the setscrew type is made of seamless, pure electrolytic copper with a heavy brass check-proof shell that reduces heating. Full current-carrying capacity is evenly distributed from wire to lug. Eight sizes are available for No. 14 wire to 2,000,000 C.M. cable. Each size is suitable for a wide range of wire. One or two hole types are available



with square or round ends. Special sizes and angular types of Screw-Tite lugs are also available. Approved by Underwriters' Laboratories. Ideal Commutator Dresser Co., 1446 Park Ave., Sycamore, Ill.

Journal Bearings

Solid and split journal bearings of a new and improved line have machined bases and faced ends with accurate dimensions, modern rounded lines and smooth gunmetal finish. Height to center line of shaft is rigidly maintained. Babbitted bores are broached to smooth hard surfaces and require no wearing in. Both styles are tapped for grease cups or pressure fittings. An ample



storage groove in the top provides proper distribution of lubricant. In addition, the split bearing has feeder grooves on each side. Individual containers are furnished for easy handling and protection in shipping. Jeffry Manufacturing Co., Columbus, Ohio.

Manufacturers' Publications

Materials

HYDRAULIC CONTROL HOSE—B. F. Goodrich Co., Akron, Ohio. Catalog Section 4030, 4 pages, 8½x11 in. Describes functions of hydraulic control hose, its uses, and manufacturing features of the Goodrich line. Couplings, spring guards and adapters are also listed.

PACKINGS — Johns-Manville, 22 E. 40th St., New York, N. Y. Form PK-12A, 44 pages, 8½x11 in. In addition to information on J-M packing and gasket styles, includes handy recommendation tables for proper packing selection.

STEEL AND TUBES—A. B. Murray Co., Inc., 145-165 Wolcott St., Brooklyn, N. Y. Stock List 3, 60 pages, 4½x8 in. Complete listing of Murray plates, sheets, tubes, boiler fittings and heads, and rolled sections.

TAPE—B. F. Goodrich Co., Akron, Ohio. Catalog Section 9270, 4 pages, 8½x11 in. Illustrates and describes "Two-In-One" tape which combines functions of splicing compound and friction tape.

TUBES—Steel & Tubes Div., Republic Steel Corp., Cleveland, Ohio. Wall chart, 22x14 in. Compiles electric resistance welded tube data on sizes, tolerances, weights per foot, chemical analyses and physical properties of round tubing, squares and rectangles. Data is standard for the industry.

Mechanical Parts

AIR COMPRESSORS — Quincy Compressor Co., Quincy, Ill. New compressor selector which functions like a slide rule aids in selecting correct size and type of compressor for a specific job.

BALL BEARINGS — New Departure Div., General Motors Sales Corp., Bristol, Conn. 15th Handbook, 156 pages, 6x8¾ in. Lists principal types and sizes of forged steel bearings. In addition to dimensions, capacities, tolerances and mounting fits, contains new data to simplify the selection of bearings. The Handbook is finger indexed for quick reference.

BELLOWS—Fulton Sylphon Co., Knoxville, Tenn. Bulletin 130, 28 pages, 8½x11 in. General treatise on seamless metal bellows and bellows assemblies indicates fundamental applications, describes both roll-formed and hydraulically-formed bellows, and describes various considerations in bellows design.

COUPLED REDUCTION GEARS — Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Booklet B-2278, 8 pages, 8½x11 in. Describes coupled reduction gears for driving compressors, line shafts, generators, etc. Cross-section drawings marked with arrows show position of important parts and dimensions.

CYLINDERS—Hanna Engineering Works, 1765 Elston Ave., Chicago, Ill. Catalog 230, 28 pages, 8½ x 11 in. Describes full line of Hanna hydraulic and air cylinders, including valuable engineering data and specifications.

FASTENERS—United-Carr Fastener Corp., 31 Ames St., Cambridge, Mass. Catalog 40, 32 pages, 8½x11 in. Complete line of "Dot" fasteners is illustrated and briefly described, with prices listed.

LUBRICATING SYSTEMS — Alemite Div., Stewart-Warner Corp., 1826 Diversey Parkway, Chicago, Ill. Form 22-34, 8 pages, 8½x11 in. Describes new progressive lubricating system, and illustrates and describes all equipment necessary for its installation and operation.

PUMPS—Baldwin Southwark Div., Baldwin Locomotive Works, Philadelphia, Pa. Bulletin 106, 12 pages, 8½x11 in. Well-illustrated booklet covers horizontal and vertical triplex high-pressure hydraulic pumps, high-pressure hand pumps and hydraulic power equipment.

PUMPS—New Jersey Machine Corp., 1505 Willow Ave., Hoboken, N. J. Bulletin, 6 pages, 8½x11 in. Comprehensive catalog sets forth detailed features of the Motoair vacuum and pressure pumps.

SLIP RING STARTER—J. P. Madden, 342 Ninth Ave., Bethlehem, Pa. Bulletin, 4 pages, 8½x11 in. Describes the Slip Ring Starter, a centrifugal clutch which transmits a definite and constant torque at any speed of operation. Specifications are given.

VIBRATION CONTROL — Lord Mfg. Co., Erie, Pa. Bulletin 104, 20 pages, 8½x11 in. Excellent treatise on bonded rubber construction for vibration control. The booklet has much valuable engineering data, and includes specifications of Lord mountings.

V-BELTS—Thermoid Rubber, Div. of Thermoid Co., Trenton, N. J. Engineering manual, 80 pages, 8½x11 in. Contains complete information on the new Thermoid V-belt drives, covering both the multiple and fractional horsepower V-belts and drives.

Electrical Parts

ELECTRIC PRODUCTS—Bull Dog Electric Products Co., 7610 Jos Campau Ave., Detroit, Mich. Condensed Catalog 411, 90 pages, 8½ x 10 in. This new catalog brings up to date the listing and descriptions of Bull Dog controlling and distributing apparatus for electric light and power.

GENERATOR VOLTAGE REGULATORS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Descriptive data 31-270, 15 pages, 8½x11 in. Describes Type BJ voltage regulators for generators with indirect acting exciters. Application to medium and large a.c. generators, as well as synchronous motors and condensers is discussed.

MOTORS—General Electric Co., Schenectady, N. Y. Bulletin GEA-3580, 12 pages, 8 x 10½ in. Contains interesting highlights on the design, construction and application of the General Electric line of Tri-Clad motors.

MOTORS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Descriptive data 4004, 8 pages, 8½x11 in. Features of d.c. motors for service in mines, mills, and general industry are set forth in this new bulletin. Recent improvements are described.

MULTI-BREAKER—Trumbull Electric Mfg. Co., Plainville, Conn. Circular 333, 4 pages, 8½x10 in. The new inclosed industrial multi-breaker, 2 and 3-pole, 230 volts, a.c., is illustrated and described in this bulletin.

ROTARY CONVERTERS—Janette Mfg. Co., 556-558 W. Monroe St., Chicago, Ill. Bulletin 13-25, 8 pages, 8½x11 in. Illustrates and briefly describes Janette d.c. to a.c. rotary converters, with and without filters.

SMOKE DETECTOR — Warner Products Corp., 1019 W. Lake St., Chicago, Ill. Bulletin 102, 2 pages, 8½x11 in. Describes the photoelectric cell adapted to smoke and vapor detection in connection with air conditioning, ventilating systems, and similar applications.

Fabrication Methods

THERMIT WELDING — Metal & Thermit Corp., 120 Broadway, New York, N. Y. Booklet 18d, 30 pages, 8½ x 11 in. Describes the thermit welding process and its application, with profuse illustrations explaining the thermit reaction. Considerable data on the physical properties of thermit welds are included.

Miscellaneous

BRAZED JOINTS—Handy and Harmon, 82 Fulton St., New York, N. Y. "The Best Joint Designs for Silver Alloy Brazing," 8 pages, 8½x11 in. Good technical article discusses and illustrates most of the considerations in designing a brazed joint.

DECIMAL EQUIVALENT CHART — Continental Diamond Fibre Co., 8 Chapel St., Newark, Del. Wall chart, 23x35 in., gives decimal equivalents from $\frac{1}{64}$ to 1 in. Color bands facilitate quick reference.

METALLIZING—Metallizing Co. of America, Inc., 562 W. Washington Blvd., Chicago, Ill. "The History, Purpose and Practice of Metallizing," 52 pages, 8½x11 in. General and broad treatise of metallizing includes several pages of data and illustrations covering typical applications.

Books and Bulletins

Plastic Mold Designing

GORDON B. THAYER—*64 pages, illustrated and indexed. 6¼x9¼ in. Blue clothboard covers. Published by American Industrial Publishers, Cleveland, Ohio. Price $3.*

The task of describing the detailed processes of plastic mold design and construction is by no means easy since factors such as the behavior of plastic materials under heat and pressure must also be considered along with mechanical considerations of strength. The success of the mold design depends a great deal on the experience of the designer. Hence this text, based on practical molding experience, and illustrated with actual designs, should be of value to engineers and molders. In addition to a study of compression and injection molds, mold steels, the hobbing process and shrinkage charts are included in this concise handbook.

Switchboard Instruments

EDITED BY E. MOLLOY—*135 illustrations, 183 pages, 6x8¾ in. Blue leatherette covers. Published by Chemical Publishing Co., 234 King St., Brooklyn, N. Y. Price $2.50.*

This book, another of the "Electrical Engineer" series, is an up-to-date survey of British practice as applied to electrical switchboard instruments. Practically all the principal types of ammeters, voltmeters, wattmeters, supply meters, power-factor meters and frequency indicators are dealt with from the point of view of the engineer who specifies or services these instruments in the factory, laboratory, or power station. Wiring diagrams show the principle of operation of each type.

A.C. Motors and Control Gear

A. J. CORKER—*125 illustrations, 216 pages, 5½x7½ in. Green clothboard covers. Published by Chemical Publishing Co., 234 King St., Brooklyn, N. Y. Price $2.50.*

Each of the dozen or more different types of a.c. motors are described in detail in this book, which uses many illustrations and diagrams of British motors to show frame and rotor construction characteristic of each type. The various systems of starting and control, varying from simple line-starters to more intricate types and pole-changing control gear are also described. Circuit diagrams showing the internal arrangements of starters and control gear, and showing wiring connections are included.

Although the book is written primarily for the factory electrical engineer, it has considerable background value to the design engineer.

Mechanism

STANTON E. WINSTON—*199 illustrations, 372 pages, 6x8½ in. Blue clothboard covers. Published by American Technical Society, Chicago, Ill. Price $3.50.*

This text on mechanism is published as a companion volume to the author's "Machine Design," and deals only with mechanical movements and the combinations of links and machine elements by which these movements are transmitted. The author does not attempt to describe every combination of links and mechanisms, but rather emphasizes the basic theory of the subject.

After discussing fundamental considerations, Mr. Winston deals with motion, instant centers and instantaneous motion, relative velocities and velocity diagrams. Proceeding from these general theories of linkages, the author attacks special problems of wrapping connectors, direct-contact mechanisms, gears, trains and cams.

The book contains many graphical constructions and Mr. Winston does a good job of explaining these, both in his drawings and in his text.

• • •

Possible Substitutes for Nickel Steels

80 pages, 6x9. Published by American Iron and Steel Institute, 350 Fifth Ave., New York. Price 25 cents.

Increased demands for nickel in defense and the difficulties in any program of substitution has prompted the preparation of data to assist in the selection and application of constructional alloy steels containing not more than 5.25 percent nickel, 1.5 percent chromium, 0.75 percent molybdenum, 2.00 percent manganese, 2.00 percent silicon, and 0.20 percent vanadium. It is anticipated that many of these substitutions may involve changes in fabricating methods, heat-treatment procedures, and facilities for its control.

The report was made possible by the fact that the effects of alloying elements have been explored and recorded systematically. Most of the data, therefore, is presented in the form of graphs, charts, and tables. Separate parts deal with four classes of carburizing steels (17 pages), three classes of thorough-hardening steels (50 pages), and low carbon alloy steels (1 page).

Ball Bearing Shop Manual

16 pages, 8½x11 in. Published by New Departure, Div. General Motors Corp., Bristol, Conn.

This excellent manual discusses and illustrates nearly every point that comes up in the design of seats for ball bearings and in the shop handling of the bearings. The booklet first discusses the general types of ball bearings, their parts and construction. Many sketches show the rights and wrongs of machining, mounting, assembling, removing, cleaning, lubricating and preloading.

Selection and Maintenance Of Rubber Transmission Belts

Catalog Section 2150, 12 pages, 8½x11 in. Published by B. F. Goodrich Co., Akron, Ohio.

Economical use of flat rubber belting is largely dependent on the selection of the right belt for the drive and this publication leads its reader by logical, orderly and simple steps to the solution of what formerly was an intricate engineering problem. In addition to discussing the necessary correction factors, the bulletin presents a chart for Arc of Contact and tables for Service Factor, Belt Speeds, Horsepower Capacity and Minimum Pulley Diameters.

Fatigue Tests of Welded Joints In Structural Steel Plates

W. M. WILSON, W. H. BRUCKNER, J. V. COOMBE and R. A. WILDE—*Bulletin 327, 83 pages, 6x9 in. Published by Engineering Experiment Station, University of Illinois, Urbana, Ill. Price $1. Some copies available free.*

Although static strength of structural steel is considered 63,000 lb. per sq. in., and fatigue strength of machined specimens is considered 47,000 lb. per sq. in., early reports of welded structures having a fatigue strength as low as 15,000 lb. per sq. in. convinced engineers that fatigue tests of welded joints, as large as it was feasible to test, were necessary before adopting welding for structures.

Tests described in this bulletin were planned to determine:

(1) The fatigue strength of butt welds in ⅞-in. carbon-steel plates.

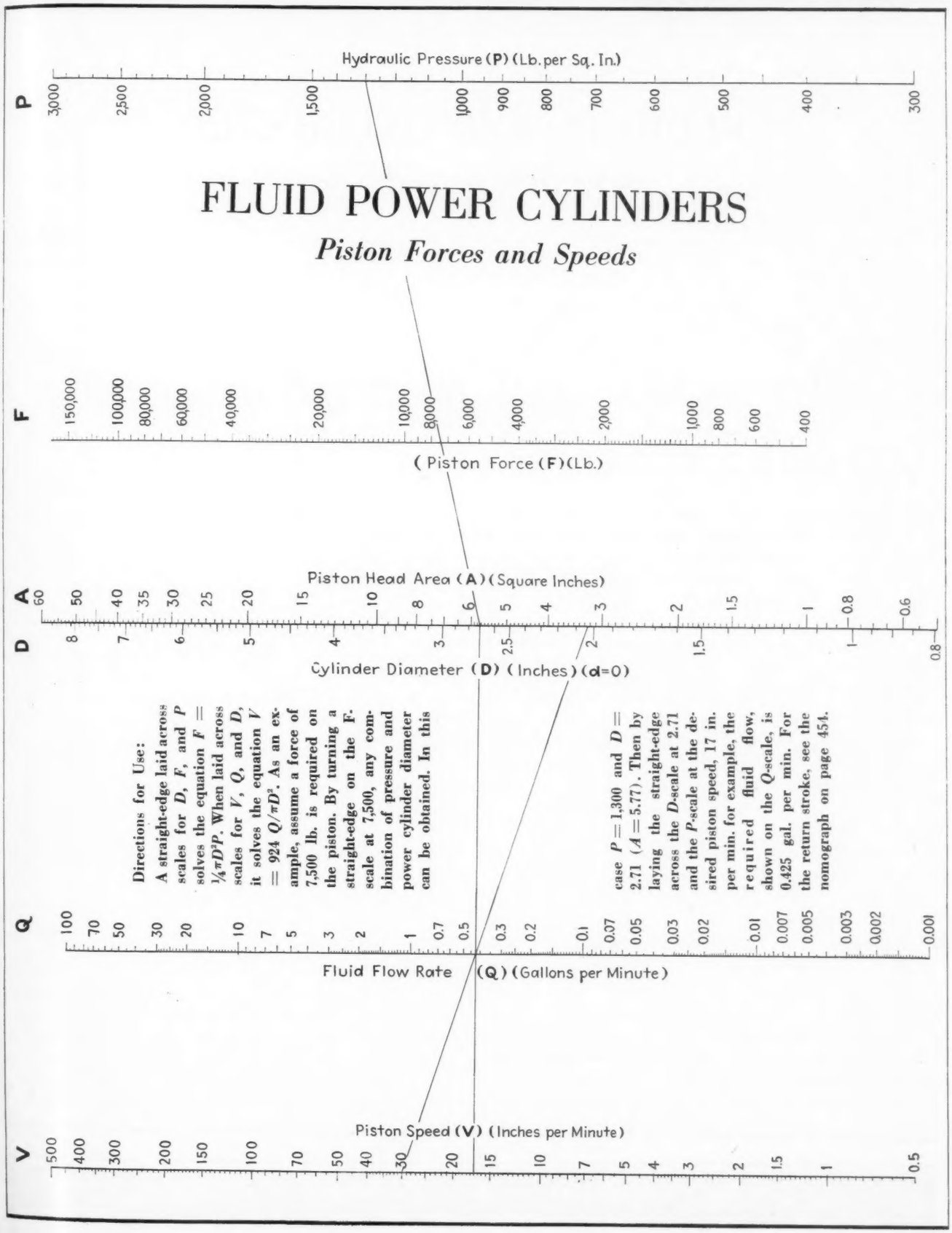
(2) The relative fatigue strength of welded and riveted joints in low-alloy plates.

(3) The effect of frequent periods of rest upon the fatigue strength of butt welds in carbon-steel plates of structural grade.

(4) The effect of transverse fillet welds.

FLUID POWER CYLINDERS

Piston Forces and Speeds

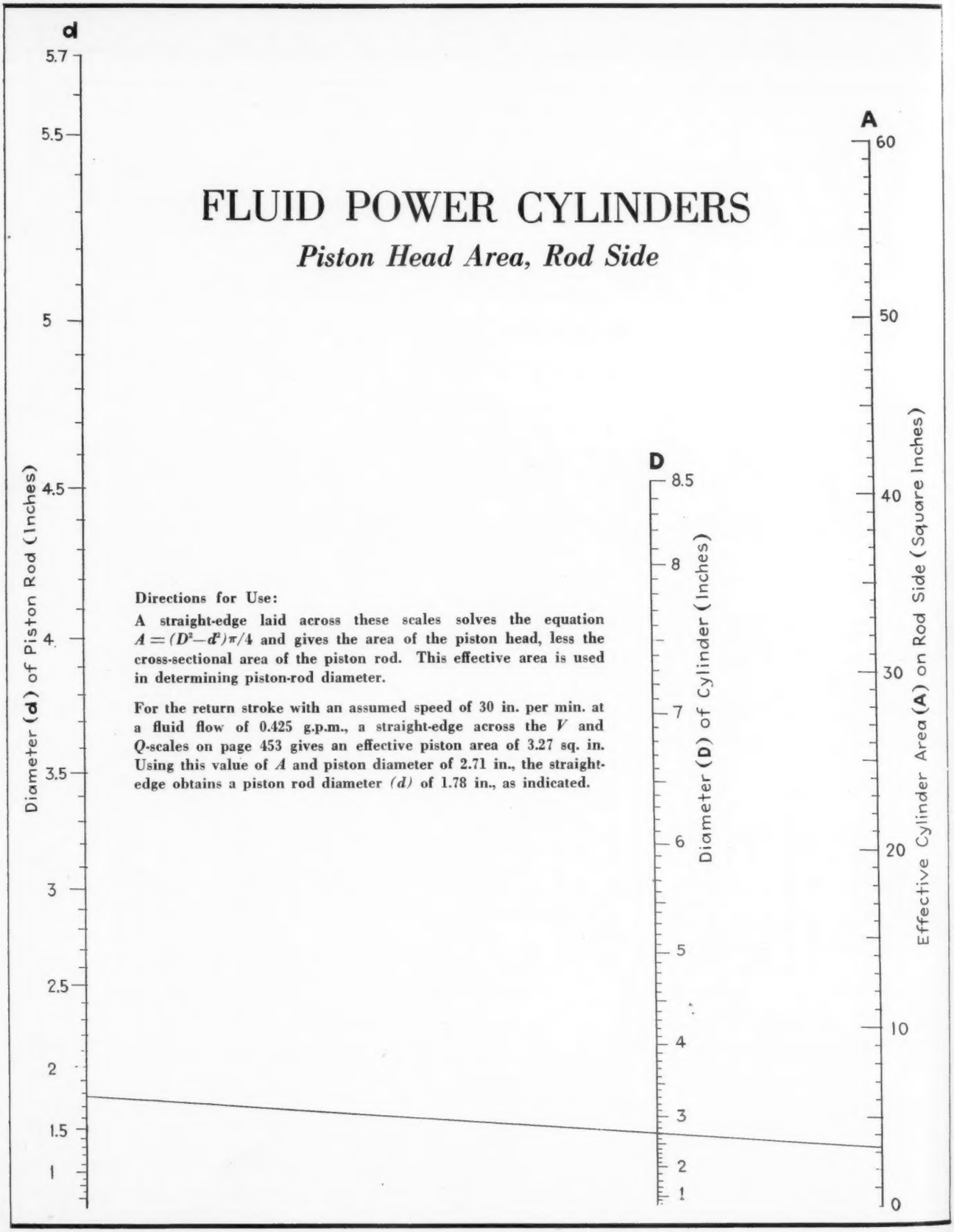


Directions for Use:

A straight-edge laid across scales for *D*, *F*, and *P* solves the equation $F = \frac{1}{4}\pi D^2 P$. When laid across scales for *V*, *Q*, and *D*, it solves the equation $V = 924\,Q/\pi D^2$. As an example, assume a force of 7,500 lb. is required on the piston. By turning a straight-edge on the F-scale at 7,500, any combination of pressure and power cylinder diameter can be obtained. In this case $P = 1{,}300$ and $D = 2.71$ ($A = 5.77$). Then by laying the straight-edge across the *D*-scale at 2.71 and the *P*-scale at the desired piston speed, 17 in. per min. for example, the required fluid flow, shown on the *Q*-scale, is 0.425 gal. per min. For the return stroke, see the nomograph on page 454.

FLUID POWER CYLINDERS

Piston Head Area, Rod Side



Directions for Use:

A straight-edge laid across these scales solves the equation $A = (D^2 - d^2)\pi/4$ and gives the area of the piston head, less the cross-sectional area of the piston rod. This effective area is used in determining piston-rod diameter.

For the return stroke with an assumed speed of 30 in. per min. at a fluid flow of 0.425 g.p.m., a straight-edge across the *V* and *Q*-scales on page 453 gives an effective piston area of 3.27 sq. in. Using this value of *A* and piston diameter of 2.71 in., the straight-edge obtains a piston rod diameter *(d)* of 1.78 in., as indicated.

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